Chemistry is the Central Science

UNIT 1

Chapter 1: Chemistry and Measurement.

Chapter 2: Nanotechnology and Chemistry.

Unit Objectives

By the end of this unit, the student will be able to :

- Identify what is chemistry.
- Explain the relationship between chemistry and the other branches of science.
- Identify the nature of measurement and its importance.
- Mention the tools and apparatuses used in chemistry labs.
- Use practical tools which are suitable for the curriculum with accuracy and efficiency.
- Understand the concept of Nanotechnology.
- Specify some of the applications of the chemistry of Nanotechnology.
- Conclude that some of the applications of Nanotechnology have useful effects, while others are harmful.

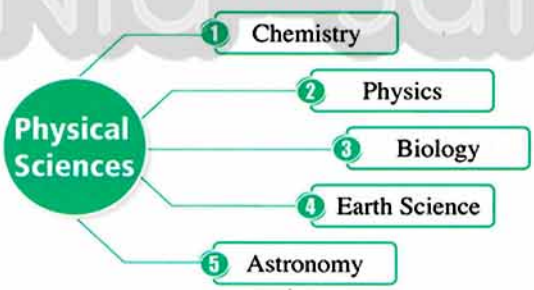
Chapter 1 Chemistry and Measurement

Since the creation of man, he is searching and exploring the surrounding universe to **understand** its phenomena, **explain** it and to even **control** it. All of what man had reached from his researches is coordinated in a structure called "**Science**".

Science

It is an organized structure of knowledge that includes facts, concepts, principles, laws, scientific theories and an organized method in research and investigation.

- The field of science differs according to :
  - The different phenomena under study.
  - The used methods in research.
  - The used tools.
- One of the major branches of science is the **Physical Sciences** which include :



So, **Chemistry** is one of the **Physical Sciences**.

Chemistry

It is the science that is interested in studying the composition and properties of matter, the changes that occur on it, the reactions of different substances with each other and the suitable conditions for these reactions.

Some applications of chemistry

- The ancient Egyptians used some chemicals in mummifying their dead.
- **Since the ancient civilizations, chemistry has been related to :**
  - metals and mining.
  - medicine.
  - some technical industries :
    - tanning.
    - dyeing of clothes.
    - production of glass.
    - production of colors.

Chemistry has been divided into branches like :

1. Physical chemistry.
2. Biochemistry.
3. Organic chemistry.
4. Analytical chemistry.
5. Thermochemistry.
6. Nuclear chemistry.
7. Electrical chemistry (Electrochemistry).
8. Environmental chemistry.

The fields of studying chemistry

The science of chemistry is interested in :

1. **Studying** the atomic and molecular structure of the matter (the bonds within it) to identify the properties of the matter quantitatively and qualitatively.
2. **Understanding** and **controlling** the chemical reactions and their conditions.
3. **Obtaining** new beneficial products that can be used in medicine, agriculture, engineering and industry.
4. **Treating** some environmental problems such as : Rust, pollution of water - air - soil , the shortage of water and energy resources.

The molecular structure of table salt crystals

UNIT 1

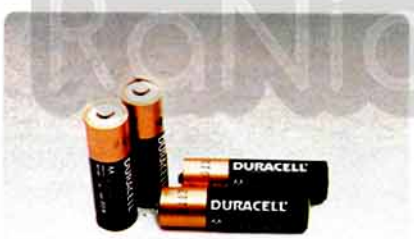
☆ **Observe the following figures and clarify the relationship between chemistry and your life.**

The pharmacological industry is one of the most important applications of chemistry.

All food consist of chemicals even if they are "organically grown".

Fuel and all parts of the car are made up of chemicals.

The dyeing of fabrics is a chemical process.



Chemical reactions can be used to produce electricity.

Water treatment and purification is an important chemical method.

From the previous, we observed that chemistry is related to many fields in our life.

Chemistry is the central science

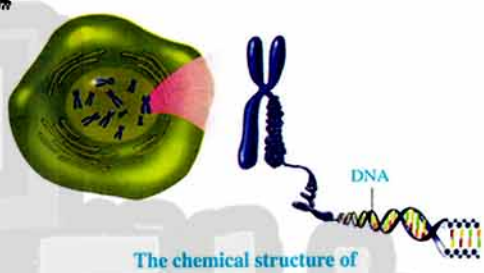
Chemistry is considered the centre of most other sciences ... GR.
Because it is essential to understand the other sciences.

Examples

1. Biology.
2. Physics.
3. Medicine and pharmacy.
4. Agriculture.
5. Future sciences.

1 Chemistry and Biology

- Biology is interested in studying the living organisms.
- Chemistry is interested in the chemical reactions that occur inside the living organisms (e.g. digestion, respiration and photosynthesis).
- Chemistry is integrated with biology in a science called **Biochemistry**.



The chemical structure of the nucleic acid in the cell

Biochemistry

It is the science that is interested in studying the chemical structure of the parts of the cell in the various organisms (e.g. carbohydrates, fats, proteins and nucleic acids).

2 Chemistry and Physics

- Physics is interested in :
  - Studying all about the matter like its movement and energy.
  - Inventing new methods for measuring more accurately to understand the natural phenomena.
- Chemistry is integrated with physics in a science called **Physical chemistry** which studies the **properties** and **structure** of matter.


The magnetic properties of the iron filings

Physical chemistry

It is the science that is interested in studying the properties and structure of the matter and the particles that form these matter.

- The physical chemistry allows the physicists to perform their studies in an easier method. GR.
  ⇨ Because it studies the properties and structure of the matter and the particles that form these matter.

UNIT 1

3 Chemistry, Medicine and Pharmacy

Medicines

They are chemical compounds that have healing properties and can be extracted from natural sources or prepared in laboratories.

- Chemistry plays an important role in each of medicine and pharmacy fields. GR.
  ⟹ By knowing the nature of functions of the hormones and enzymes and explaining the role of medicine inside the human body.

4 Chemistry and Agriculture

Chemistry helps in agriculture by :

- Selecting the suitable soil for planting a certain crop by the chemical analysis which determines the ratios of the soil components and the degree of sufficiency of these components for this plant or crop.
- Increasing the productivity of crops, as chemistry can prepare the suitable fertilizers for each crop and also the insecticides to get rid of the agricultural pests.

N P K

Essential elements in chemical fertilizers

5 Chemistry and the Future

We can discover and form some substances with extraordinary properties through using Nanochemistry.

Nanochemistry

It is the science that is interested in discovering and forming new substances with extraordinary properties that may be used for improving of various fields to provide numerous human needs.

As we will study in the next chapter, these substances may be used for improving of various fields like engineering, communications, medicine, the environment, transportation and provide numerous human needs.

Measurement in Chemistry

The advancement of the scientific, industrial, technological and economical fields is the result of the correct and accurate use of Measurement principles.

Measurement

It is the comparison of an unknown quantity with another quantity of the same kind in order to know the number of times which the first includes the second.

Any measurement process must include two main points, which are :

1. **Numerical value :** describes the measured property.
2. **Suitable measuring unit :** indicates a certain standard to which the measured quantity is being referred.

Numerical value — Measuring unit

61.2 kilogram

The measuring unit

It is a certain portion of a certain physical amount and used as an indicator to measure an actual portion for this amount.

Example

When we say that the length of the football playing field is 100 yd.

We mean that the field is 100 times longer than the standard of length is called Yard (yd).

Enrichment information

The French scientist, Antoine Lavoisier, is considered responsible for making chemistry a precise quantitative science. As his experiments were completely of the quantitative type. He was the first to identify the composition of the phosphorus acid and nitric acid. Lavoisier wrote the law of conservation of mass.
His work gave a strong push toward the advancement of the measuring tools and apparatuses in chemistry.

The importance of measurement in chemistry

Measurement provides us with necessary information and quantitative data to help us making a proper decision and following up the required procedures, as follows :

1. Giving information about the type and the concentration of elements forming the substance.
2. Monitoring and health protection.
3. Diagnosing and suggesting the suitable medication in case of defects (diseases).

1 Measurement gives information about the type and the concentration of the elements forming the substances which we use :

The following table shows the components of two bottles of mineral water expressed in mg/L (milligram/litre) unit.

Components	Na^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	$(HCO_3)^-$	$(SO_4)^{2-}$
Bottle (A)	25.5	2.8	8.7	12	14.2	103.7	41.7
Bottle (B)	120	8	40	70	220	335	20

1. Suppose a consumer follows a nutritional system with low salts, which bottle will he choose ?

It is preferred to choose bottle (A), because it contains lower amount of salts.

UNIT 1

② A person has consumed 1.5 L/day from bottle (B). **Calculate** the mass of calcium that he gained from this amount of water during the day.

From the table we know that in bottle (B) : 1 L $\xrightarrow{\text{contains}}$ 70 mg

1.5 L $\xrightarrow{\text{contains}}$? mg

So, the mass of calcium $= \frac{1.5 \times 70}{1} = 105$ mg

2 Measurement is necessary for monitoring and health protection :

The safety of the environment and its protection requires :

– the monitoring of drinking water.

– the puirty of air we breath.

– the healthy of food substances and agricultural products.

• Use the following table which shows the international standards of the drinking water components to examine the quality of water in **the two previous bottles**.

Components	Na^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	$(SO_4)^{2-}$
Quantity (mg/L)	< 150	< 12	< 50	< 300	200 – 250	< 250

⟹ From the two previous tables we can conclude that the two bottles are valid for drinking.

3 Diagnosing and suggesting the suitable medication in case of defects (diseases) :

• Medical analysis reports indicate the health status of patients referring to medical analysis values of healthy persons which are known as "reference values".

• Use the opposite medical analysis report to clarify the following :

Medical Analysis Report		
Type	Value of analysis (mg/dL)	Reference Value (mg/dL)
Glucose	70	70 – 110
Uric acid	9.2	3.6 – 8.3

① **What does the reference value mean ?**

The reference value means the normal limits of lowest and highest values obtained on normal healthy people.

② **What is your conclusion about these results ?**

The amount of **glucose** is normal, but the amount of **uric acid** is abnormal, it is higher than the highest reference value.

③ **What are the decisions that this person has to take ?**

He has to go to the doctor to take a proper medicine to treat this defect, then make a medical analysis to show how well the treatment is working.

Measuring tools in the chemistry laboratory

- Chemical experiments are carried out in the chemistry laboratory. GR.

⇨ Because they require :

- Safety precautions.
- A source of water.
- A source of heat (e.g. Bunsen flame).
- Cupboards and shelves to store chemicals, tools and various apparatuses.

- It is necessary to know how you can use each of these tools and apparatuses.

In the following we will discuss some of these tools and apparatuses.

1 The sensitive balance

- Digital balances are the most common.
- The top loading balance is the most commonly used of the digital balances.
- Before using the balance, you have to read the instructions which are present on one of its sides.

Top loading digital balance

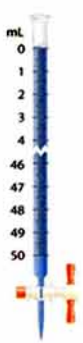
Usage

- It is used to measure the mass of substances.

2 Burette

- The burette is a long glass tube with two openings, the upper one is used to fill the burette with a solution and the other lower opening has a fixed valve to control the amount of solution taken from it.
- The burette is fixed on a holder with a metallic base to preserve its vertical shape through the experiments.
- In the burette, the graduation zero is close to the upper opening and ends before the valve.

A burette fixed on a stand



The burette scale

Usage

- It is used to measure volumes of the solutions with a high degree of accuracy during titration.

UNIT 1

3 Beakers

Transparent beakers are made of **Pyrex glass** (resisting to heat).

Usage

1. Mixing the liquids and solutions.
2. Measuring the approximate volumes of solutions.
3. Transporting a known volume of liquid.

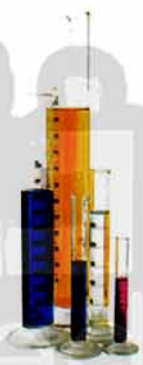
Beakers with various volumes

4 Graduated cylinders

Graduated cylinders are made of **glass** or **plastic**.

Usage

1. Measuring the volume of liquids where they are more accurate than flasks.
2. Determining the volume of a solid body which doesn't dissolve in water.

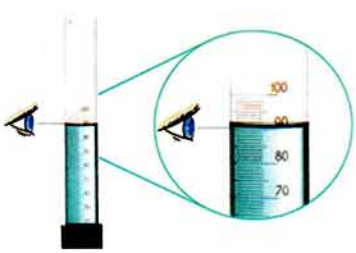


Graduated cylinders

How can you determine the volume of a liquid by a graduated cylinder ?

By recording the reading at **lower point of the concave surface of the liquid**, keeping your eyes on the same level of the liquid.

☆ **The correct reading for the liquid volume here = 90 mL**



5 Flasks

- Flasks are made of **Pyrex glass**.
- Flasks have many different capacities.

There are various types of flasks, according to their function like :

Conical flask
It is used in titration.

Round-bottom flask
It is used in the chemical preparation and distillation.

Volumetric flask
It is used to prepare solutions with very accurate known concentrations (the standard solutions).

- Volumetric flask has a mark on its top. **GR.**

⇒ To determine the water volume that is added to prepare a solution with a known concentration.

6 Pipette

- It is a long glass tube opened from the two sides, recorded on it the **volume capacity** and the **error percentage**.

Graduated pipette

Pipette with two bulbs

For Illustration

Error percentage :
The error percentage may be produced from the apparatus used or the circumstances of its usage and also from the human error resulting from the apparatus user.

UNIT 1

Usage

- It is used to accurately **measure** and **transport** a certain volume of solution.

☆ **Way of usage :**

- Some of them are filled by mouth sucking and this **must be with care**.
- The others are supported with a sucking tool and these are used with very hazardous materials.

7 Measuring tools for pH value

- The term **pH** refers to the concentration of hydrogen ions H^+ in the aqueous solutions.
- Its value ranges from **0 – 14**

Usage

- The pH value determines if the solution is **acidic**, **basic** or **neutral**.

if pH < 7	if pH = 7	if pH > 7
The solution is acidic.	The solution is neutral.	The solution is basic or alkaline.

☆ **The determination of pH value is very important in chemical and biochemical reactions.**

So, there are many tools to detect pH value such as :

A pH test paper tape

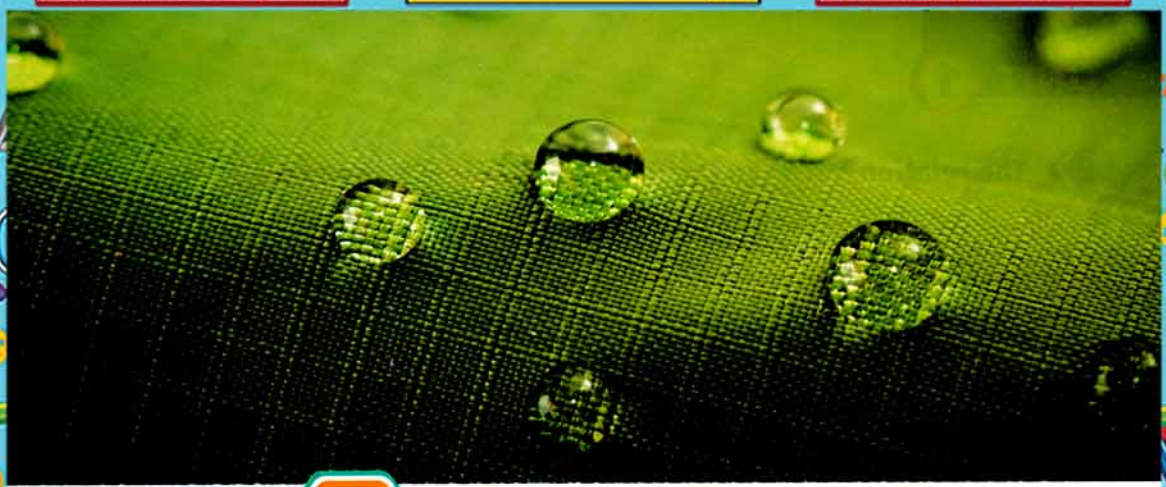
- It is a porous paper saturated with an indicator solution and dried.
- When this paper is wetted with the solution under test, it gains a certain color which indicates a certain pH value.

A solution of pH value = 7

B pH-meter

- It is more accurate digital apparatus, when it is immersed in the solution, the pH value appears directly on the digital screen.

A solution of pH value = 3.2



Chapter 2 Nanotechnology and Chemistry

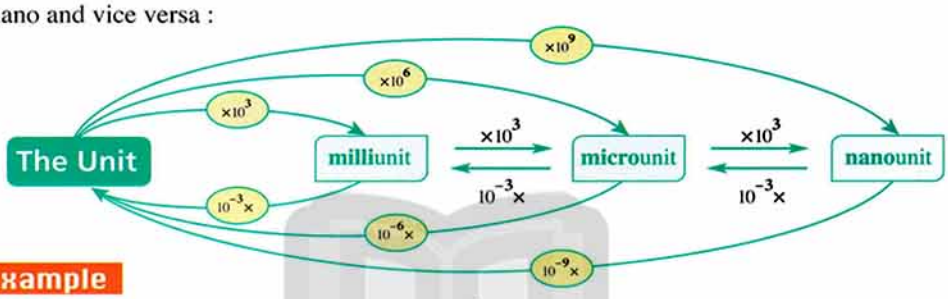
- There are some derived words from the SI basic units differ from each others by powers of ten (10^n). These derived words are called **SI Prefixes.**
- **The following table shows some of SI Prefixes :**

SI Prefixes	Abbreviation	Multiple (10^n)	Examples
Giga	G	10^9	1 **Giga**watt = 10^9 watt
Mega	M	10^6	1 **Mega**hertz = 10^6 Hertz
Kilo	k	10^3	1 **Kilo**meter = 10^3 meter 1 km = 10^3 m
Deci	d	10^{-1}	1 **Deci**meter = 10^{-1} meter 1 dm = 10^{-1} m
Centi	c	10^{-2}	1 **Centi**meter = 10^{-2} meter 1 cm = 10^{-2} m
Milli	m	10^{-3}	1 **Milli**meter = 10^{-3} meter 1 mm = 10^{-3} m
Micro	μ	10^{-6}	1 **Micro**meter = 10^{-6} meter 1 μm = 10^{-6} m
Nano	n	10^{-9}	1 **Nano**meter = 10^{-9} meter 1 nm = 10^{-9} m
Femto	f	10^{-15}	1 **Femto**second = 10^{-15} sec

UNIT 1

The relation between the milli, the micro and the nano

- milli ($\frac{1}{1000}$ of unit) > micro ($\frac{1}{1000\,000}$ of unit) > nano ($\frac{1}{1000\,000\,000}$ of unit).
- The following diagram shows how to convert from the measuring unit to its milli, micro or nano and vice versa :



Example

Calculate the value of :

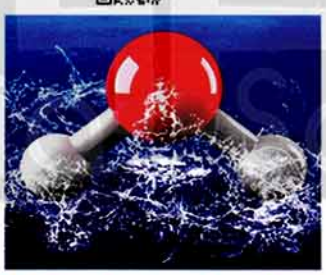
1. 42.3 millimeter by meter unit.
2. 0.03 second by nanosec. unit.
3. 497.3 mg by microgram unit.

Solution

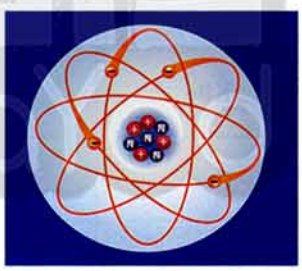
1. $42.3\ nm = 42.3 \times 10^{-3}\ m = 0.0423\ m$
2. $0.03\ s = 0.03 \times 10^{9}\ ns = 3 \times 10^{7}\ ns$
3. $497.3\ mg = 497.3 \times 10^{3}\ \mu g$

- Nanometer is used as a measuring unit for very minute particles like atoms and molecules as shown in the following figures :

The diameter of a sand grain $\simeq 10^6$ nm (1 mm)



The diameter of a water molecule is approximately 0.3 nm



The diameter of an atom ranges 0.1 : 0.3 nm

Nano scale

It is the scale of the extremely small particles of less than 100 nm.

☆ **Substances gain unique properties on the Nano scale differ from their properties on macro or micro scales.**

These properties change according to the change in the Nano volume and they are called :

Volume dependent properties.

For Illustration

Macro : can be seen by a naked eye (> 1 mm)
Micro : can be seen under a microscope (100 : 1000 μm)

Critical Nano volume

It is the volume in which the unique Nano properties of the substance appear and it is less than 100 nm.

Examples of Nano properties

1 The change of gold color according to the change of the Nano volume.

- It's common that gold has a bright yellow color, but on reducing its particles volume to the Nano volume, it takes different colors like : Red, orange, green or blue according to the Nano volume.

Changing the gold color according to its Nano volume

- The change of gold color on changing its volume from macro scale into Nano scale. GR.

⇨ Because the reaction of gold particles in Nano scale with light differs from its reaction with light in macro scale.

2 The change of the copper hardness according to the Nano volume.

- The hardness of copper increases by decreasing the volume of its particles to be in Nano volume.

Nano copper powder

Interpretation of the unique (unusual) behavior of Nano substances.

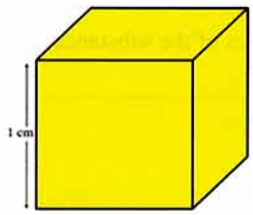
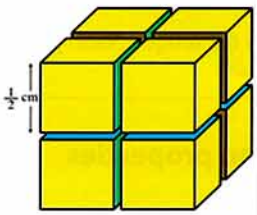
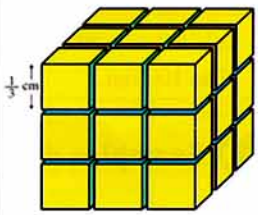
- The unique (unusual) properties of nanomatter are due to the relation (ratio) between the surface area and its volume.

Application

Relation between surface area and volume of a cube.

On dividing a cube of a side length of 1 cm to many cubes, the total surface areas of cubes increases, while the total volume of cubes still constant, as shown in the following table :

UNIT 1

Figures			
Length of the cube side (L)	1 cm	$\frac{1}{2}$ cm	$\frac{1}{3}$ cm
Number of cubes	1	8	27
Total surface area = (6 L^2) × (no. of cubes)	$1 \times 6 \times (1\text{ cm})^2 = 6\text{ cm}^2$	$8 \times 6 \times (\frac{1}{2}\text{ cm})^2 = 12\text{ cm}^2$	$27 \times 6 \times (\frac{1}{3}\text{ cm})^2 = 18\text{ cm}^2$
Total volume = L^3 × (no. of cubes)	$(1\text{ cm})^3$ 1 cm^3	$8 \times (\frac{1}{2}\text{ cm})^3$ 1 cm^3	$27 \times (\frac{1}{3}\text{ cm})^3$ 1 cm^3
Surface area / Volume	$\frac{6}{1} = 6$	$\frac{12}{1} = 12$	$\frac{18}{1} = 18$

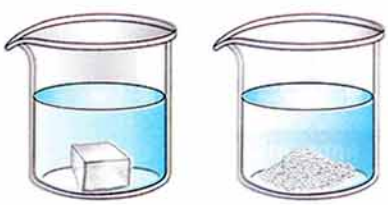
With more division of the cube, the ratio between surface area and volume increases.

What happens if the division continues until we reach a cube of a length ≃ 1 nm ?

The ratio between the surface area and the volume **will increase** to a very large value. So, more number of atoms will be exposed to the reaction at the same time. So, the reaction will be faster.

Example

- This idea can be understood also if you add two equal masses of sugar, one of them is fine powdered and the other one is a block cube in equal volumes of water at the same temperature.



- It is clear that fine powdered sugar dissolves in water faster than a block cube. GR.

  ⇨ Because sugar powder has a greater ratio between the surface area and the volume than that of a sugar cube. So, more number of molecules will be exposed to the dissolving process at the same time.

From the previous we can conclude that

- **The very large ratio between the surface area and the volume of Nano particles will give it new and unique physical and chemical properties like :**
  - **Chemical properties like :** The speed of chemical reactions.
  - **Physical properties like :** Color, transparency, melting point, heat and electric conductivity.
  - **Mechanical properties like :** Toughness and elasticity.

☆ What is meant by Nanotechnology ?

"Nanotechnology" is a term of two words

Nano

It is derived from the Greek word "Nanos" which means "Dwarf" (i.e. very small).

Technology

It means the application of knowledge in a certain field.

Nanotechnology

It is the technology of very small substances and it specializes in treating the substances on the Nano scale to produce resultants with new, useful and unique properties.

Nanochemistry

Nanochemistry : It is one of the **Nano science branches** which :

1. Deals with chemical applications of Nano substances.
2. Includes studying, description and the synthesis of Nano substances.
3. Studies the unique properties related to collecting atoms and molecules of Nano dimensions.

Nano substances may take different shapes as follows

- **Particles.**
- **Nano columns.**
- **Nano wires.**
- **Balls.**
- **Nano tubes.**
- **Nano fibres.**
- **Thin films.**

UNIT 1

Nano substances are classified according to their Nano dimensions into :

1. One-dimensional Nano substances
2. Two-dimensional Nano substances
3. Three-dimensional Nano substances

1 One-dimensional Nano substances

One-dimensional Nano substances

They are the Nano substances that have one Nano dimension.

Examples

Thin films

Used in

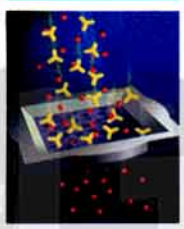
1. Packaging food products to protect them from getting spoiled or rotten.
2. Painting surfaces to protect them from rust and corrosion.

Nano wires

Used in

Electric circuits.

Nano fibres



Used in

The production of water filters.

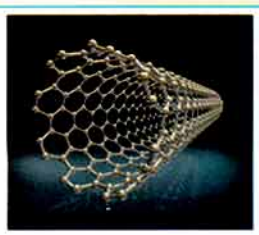
2 Two-dimensional Nano substances

Two-dimensional Nano substances

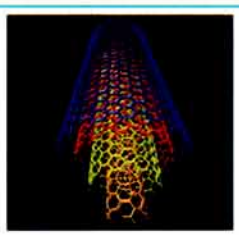
They are the Nano substances that have two Nano dimensions.

Examples

Unicarbon Nano tube



Multicarbon Nano tube



Carbon Nano tubes are :

1. Good conductors of electricity more than copper.
2. Good conductors of heat more than diamond.
3. Stronger and lighter than steel, due to the powerful bonds between its molecules, therefore the Nano tubes which have the size of a human hair can easily pull a truck. So, scientists think to make very strong robes that can be used in the future to make space elevators (shuttles).
4. Connected easily to protein. So, they can be used in making biological sensor devices which are sensitive to a certain molecules.

Give reasons :

1. **Carbon Nano tubes are stronger than steel.**
   Due to the powerful bonds between its molecules.
2. **The scientists try to use the Nano tubes to make space elevators.**
   Because they are stronger and lighter than steel.
3. **The carbon Nano tubes can be used in making biological sensor devices.**
   Because they are connected easily to protein and they are sensitive to a certain molecules.

3 Three-dimensional Nano substances

Three-dimensional Nano substances

They are the Nano substances that have three Nano dimensions.

Examples

Bucky ball C60

1. Bucky ball C60 consists of 60 carbon atoms.
2. It is characterized by a group of special properties, which depend on its molecular structure.
3. The molecular model of the bucky ball appears as a hollow football. So, the scientists test the effectiveness of using it as a carrier for a medicine in the body.

Nano shell

For Illustration

Nano shell consists of :

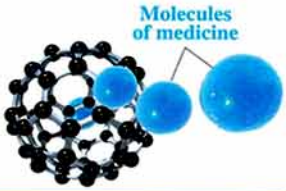
1. Core : it is made of insulator substances.
2. Shell : it is made of very thin metallic cover (almost gold).

UNIT 1

Give reasons :

Bucky ball used as a carrier for a medicine in the body.

⇒ Due to its hollow structure, it can be fitted with the molecules of a medicine and protect it from the reaction with a certain molecules inside the body.



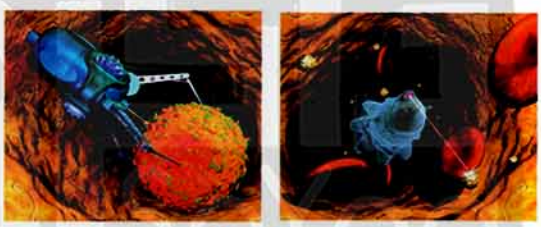
Enrichment information

Scientists have discovered that Damascus swords that Arabs and muslims used long ago have in their composition silver Nano particles that give it a great hardness.

Applications of Nanotechnology

1 Medical field

1. The early diagnosing of diseases and picturing of organs and tissues.
2. Exactly delivering of a medicine to the infected tissues and cells, which increases the chances of healing and decreases the harmful side effects of the traditional healing methods which don't distinguish between the infected cells and the other healthy ones.
3. Producing Nano robots that enter the body through the blood stream to remove blood clots from the vein walls without surgical interference.
4. Producing extremely small devices for dialysis that are implanted in the body of the patient who suffers from kidney failure.



Nano robot

Enrichment information

Dr. Mustafa El-Sayed was the first Egyptian Scientist obtained the American National Science pendant for using gold Nano molecules to treat cancer disease.

2 Agricultural field

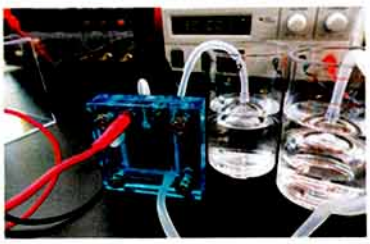
1. Identifying bacteria that found in nutrients. So, we can use this technology in preserving food.
2. Improving nutrients, pesticides and medicines for plants and animals with special features.

3 Energy field

1. Producing **solar cells** by using **Nano silicon,** which has a great ability to convert solar energy into electrical energy and avoid the leakage of heat energy.

Solar cells with Nano silicon

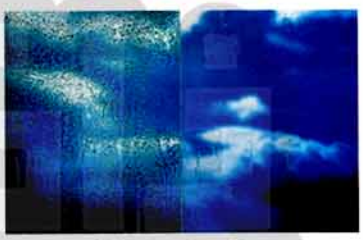
2. Producing **hydrogen fuel cells**, with a high performance and low cost.



Hydrogen fuel cells

4 Industrial field

1. Producing invisible Nano molecules, which give the glass and ceramics the property of self-cleaning.



Self-cleaning glass

2. Producing Nano substances to purify ultraviolet rays in order to improve sunblock cosmetics and creams.
3. Producing Nano wrapping technology in the form of paints and sprays to protect the screens of electrical devices from scratching.
4. Producing repellent tissues for stains that are characterized by the self-cleaning property.

Self-cleaning tissue

Do you know ?

There are some plants having leaves covered with natural substances which are repellent for stains.

UNIT 1

5 Communications field

1. Producing wireless Nano devices, mobiles and satellites.
2. Decreasing the size of transistors.
3. Producing electric chips that are characterized by a high storage capacity.

Nano transistor

6 Environmental field

Producing Nano filters which are used to :

1. Purify air and water.
2. Solve the nuclear wastes problem.
3. Eliminate the dangerous elements from the industrial wastes.

The possible harmful effects of Nanotechnology

1 Environmental effects

During the production of Nano substances, there are many wastes may be suspended in the air, then enter water and soil and they may easily penetrate the animal and plant cells, this is called **Nano pollution**.

Nano pollution

It is the pollution caused by the wastes produced from preparing Nano substances.

2 Medical effects

The very minute Nano particles may enter the body of human or animal through the cell membrane of the skin and lungs causing diseases.

3 Social effects

The social and economic problems between the rich world countries and the developing countries may increase, due to the unequal distribution of technology and economic resources.

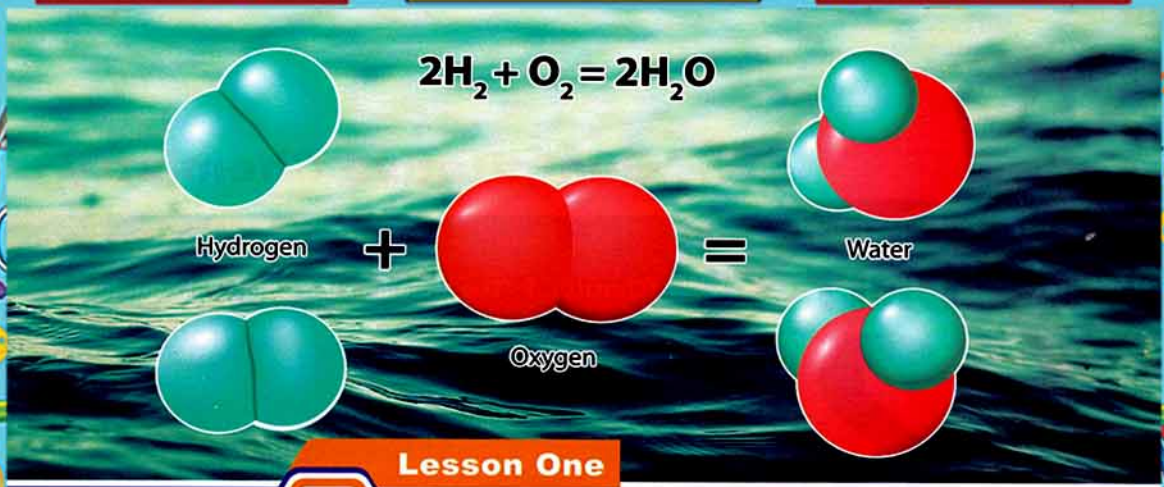
Quantitative Chemistry

UNIT 2

Unit Objectives

By the end of this unit, the student will be able to :

- Express a chemical reaction using a balanced symbolical equation.
- Calculate the mass of the mole of a chemical compound by using of the atomic mass.
- Mention the relationship between the mole and the Avogadro's number.
- Identify the molar volume of gas at (STP).
- Calculate the number of moles of gas by using its volume and molar volume.
- Calculate the mass percentage of the components of a substance by using its chemical formula or with the experimental results.
- Deduce an empirical formula and a molecular formula of the compound by using the experimental results.
- Calculate the amounts of reactants and products in the balanced chemical equation.



Lesson One

Chapter 1 The Chemical Equation

- Chemical experiments are carried out in laboratories under certain conditions, tools, ... etc.
- Such these experiments and reactions can be expressed by words or symbols, as the following reaction between magnesium and oxygen (Magnesium combustion) :

Magnesium + Oxygen $\xrightarrow{\text{heat}}$ Magnesium oxide

$2Mg + O_2 \xrightarrow[\text{reaction condition}]{\Delta} 2MgO$

Reactants — Products

The chemical equation

A group of chemical symbols and formulas of the reactants and products which are connected by an arrow that expresses the direction of this reaction and carries its conditions.

☆ **This chemical equation describes each of the reactants and the products accurately according to :**

1 The chemical symbols and molecular formulas :

It shows the kind, the number or the ratio of elements that are forming the chemical substances.

❷ **The quantity :** We can say in a quantitative manner that every 2 moles of solid magnesium react with 1 mole of oxygen gas to produce 2 moles of solid magnesium oxide.

	Reactants			Products
Quantities of reactants and products	2Mg	+	O_2	2MgO
Duplicate these quantities	4Mg	+	$2O_2$	4MgO
Divide these quantities	Mg	+	$\frac{1}{2}O_2$	MgO

❸ **The physical state :** The chemical equation shows the symbols that are used to express the physical states of the reactants and products and it is written at the bottom right of the chemical symbol.

State	Symbol	Example
Solid	(s)	$Fe_{(s)}$
Liquid	(ℓ)	$H_2O_{(\ell)}$
Gas	(g)	$O_{2(g)}$
Aqueous solution	(aq)	$NaCl_{(aq)}$

☆ **The chemical equation must be balanced where the numbers of atoms (or ions) are the same in both sides.** GR.

⇨ To achieve the law of mass conservation.

Preface Example

Write the balanced chemical equation for the reaction between hydrogen and oxygen gases to produce water.

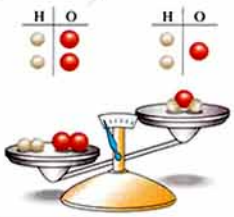
The steps	Apply on the example
❶ **Write the word equation.**	Hydrogen (gas) + Oxygen (gas) ⟶ Water (liquid)

UNIT 2

2 Write the symbolic equation.

The equation is not balanced.
Because the number of oxygen atoms produced from the reaction is lower than that entered the reaction.

$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(l)}$



3 Balance the chemical equation.

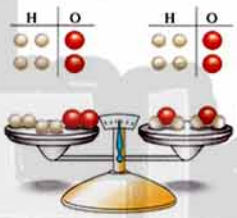
By equalizing the no. of atoms of oxygen in both sides of the equation.
Thus, the equation is balanced.
Because the number of atoms of elements produced from the reaction is equal to that entered the reaction.

- To balance oxygen multiply $H_2O \times 2$

$H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$

- To balance hydrogen multiply $H_2 \times 2$

$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$



Application

EKB

Write a balanced symbolic equation which expresses the reaction between glucose and oxygen in respiration process.

Solution

1 Write the word equation.

Glucose + Oxygen ⟶ Water + Carbon dioxide

2 Write the symbolic equation.

The equation is not balanced, because the number of C , H and O atoms produced from the reaction is lower than that entered the reaction.

$C_6H_{12}O_6 + O_2 \longrightarrow H_2O + CO_2$

C	H	O
6	12	8

C	H	O
1	2	3

3 Balance the chemical equation.

- Add 6 to carbon dioxide molecule to have the same number of C atoms in both sides.
- Add 6 to water molecule to have the same number of H atoms in both sides.
- It is found that the total O atoms in products equals 18. So, we need to add additional 6 to O_2 molecule, to have the same number of O atoms in both sides.

$$C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + H_2O$$

$$C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + 6H_2O$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

∴ The balanced equation is : $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$

Remember

Molecule : The smallest part of a substance that can be found in a single form and The properties of the substance depend on it.

Atom : The smallest building unit of the substance that can participate in chemical reactions.

The molecule and the atom are very small particles, their dimensions are expressed in the Nanometer unit and it is very difficult to deal with them practically.

Balance the following equation :

$$H_2S_{(aq)} + SO_{2(g)} \longrightarrow S_{(s)} + H_2O_{(l)}$$

Write a balanced chemical equation of the reaction between nitrogen and hydrogen gases to form ammonia gas.

Ionic Equation

Ionic equation

It is the chemical equation in which some or all reactants and products are written in the form of ions.

- **The ionic equations are used to express :**
  - **A. Some physical processes.**
  - **B. Some chemical reactions.**

A The ionic equation for some physical processes

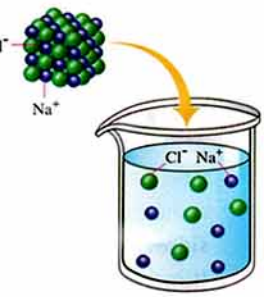
- Dissociation of some ionic compounds into ions when they are :
  - Melted.
  - Dissolved in water.

UNIT 2

Example

Dissolving of sodium chloride salt in water can be expressed by the following ionic equation :

$$NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$$



Dissolving of sodium chloride salt in water

B The ionic equations for some chemical reactions

1. **Neutralization reactions.**
2. **Precipitation reactions.**

1 The ionic equation for neutralization reactions

- The reaction of acid and base to form salt and water is called **"Neutralization reaction"**.

GR.

⇒ Because the properties of acid and base disappear when they react together.

Example 1

The reaction between sulphuric acid and sodium hydroxide is represented by the following symbolic equation :

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(\ell)}$$

But, does this equation represent the real form of the substances in the aqueous solution ?

Many substances like (acids - bases - salts) are ionized in water. So, the equation should be written as the following :

$$2H^+_{(aq)} + SO^{2-}_{4(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \longrightarrow 2Na^+_{(aq)} + SO^{2-}_{4(aq)} + 2H_2O_{(\ell)}$$

From the previous equation :

The sodium ions $Na^+_{(aq)}$ and sulphate ions $SO^{2-}_{4(aq)}$ remained free and didn't participate in the reaction. So, they can be cancelled from the both sides of the equation.

So, the ionic equation of this reaction will be written as :

$$2H^+_{(aq)} + 2OH^-_{(aq)} \longrightarrow 2H_2O_{(\ell)}$$

The ionic equation of any neutralization reaction will be :

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(\ell)}$$

Example 2

Write the ionic equation that expresses the neutralization reaction between hydrochloric acid and sodium hydroxide solution.

Solution

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(\ell)}$$

$$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(\ell)}$$

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(\ell)}$$

Note

In such these neutralization reactions, water is not found in the form of ions, but in the form of molecules.

Write the ionic equation expressing the following reaction :

Nitric acid + Potassium hydroxide solution ⟶ Potassium nitrate solution + Water

2 The ionic equation for precipitation reactions

Chemical reactions that occur between aqueous solutions of two different (soluble) salts and give (produce) solid salts insoluble in water (precipitates) are called **"Precipitation reactions"**.

Example 1

On adding potassium chromate solution to silver nitrate solution, a red precipitate of silver chromate is formed which is insoluble in water.

$$K_2CrO_{4(aq)} + 2AgNO_{3(aq)} \longrightarrow 2KNO_{3(aq)} + Ag_2CrO_{4(s)}\downarrow$$

(red precipitate)

Red precipitate of silver chromate

- The equation should be written as the following ionic form :

$$2K^+_{(aq)} + CrO^{2-}_{4(aq)} + 2Ag^+_{(aq)} + 2NO^-_{3(aq)} \longrightarrow 2K^+_{(aq)} + 2NO^-_{3(aq)} + Ag_2CrO_{4(s)}\downarrow$$

From the previous equation :

$K^+_{(aq)}$ and $NO^-_{3(aq)}$ ions remained free and didn't participate in the chemical reaction. So, they can be cancelled from the both sides of the equation to obtain the following ionic equation :

$$2Ag^+_{(aq)} + CrO^{2-}_{4(aq)} \longrightarrow Ag_2CrO_{4(s)}\downarrow$$

- The sum of charges on the left side = zero

$2Ag^+_{(aq)} + CrO^{2-}_{4(aq)} = [2 \times (+1)] + (-2) =$ zero

- The sum of charges on the right side (Ag_2CrO_4) = zero

So, the ionic equation for ionization and precipitation reactions must be balanced where :

- The sum of positive and negative charges is the same in both sides.
- The number of atoms of each element is the same in both sides.

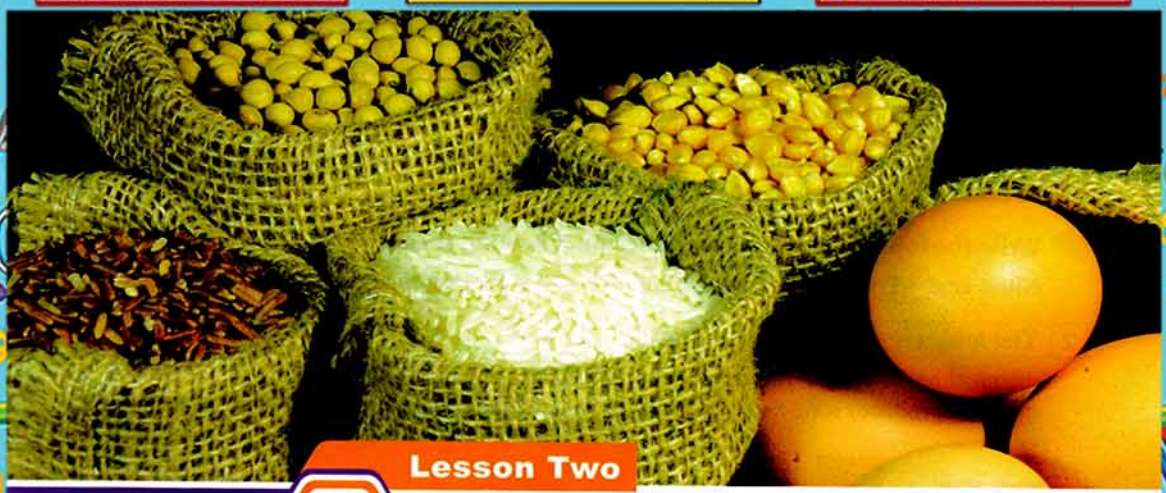
Example 2

Write the ionic equation for the following precipitation reaction.

Solution $Hg(NO_3)_{2(aq)} + Na_2S_{(aq)} \longrightarrow 2NaNO_{3(aq)} + HgS_{(s)}$

$$Hg^{2+}_{(aq)} + 2NO^-_{3(aq)} + 2Na^+_{(aq)} + S^{2-}_{(aq)} \longrightarrow 2Na^+_{(aq)} + 2NO^-_{3(aq)} + HgS_{(s)}$$

$$Hg^{2+}_{(aq)} + S^{2-}_{(aq)} \longrightarrow HgS_{(s)}$$



Lesson Two

Chapter 1 The Mole

We can't deal with limited atoms, molecules or ions in chemical reactions due to their small masses and volumes, as we use enormous numbers, where the least mass from substance contains a huge number of atoms, molecules or ions.

So, how can we relate between the mass of substances and their numbers of components ?

- To answer this question you should study "**The Mole**" concept.
- "**Mole**" is the unit of the quantity of matter in the International System of Units (SI) and it is defined by different ways according to :
  - ☆ **The mole and mass of substance.**
  - ☆ **The mole and Avogadro's number.**
  - ☆ **The mole and volume of gas.** (It will be studied at the next lesson).

The mole and mass of substance

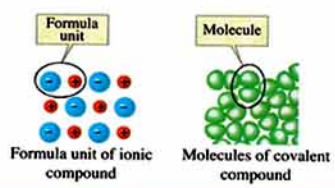
- Any substance may be found in the form of atoms, molecules or formula units.

The molar mass

It is the atomic mass, molecular mass or mass of formula unit expressed in grams.
Or, it is the mass of one mole of a substance.

Note

The structural units of covalent compounds are known as molecules, while that of ionic compounds are known as formula units.



1 If the substance is in the form of atoms (the building unit of substance is atom)

- The mass of one atom is called **atomic mass** which is very small, it differs from one atom to another one which is estimated by **atomic mass unit (amu)** or **u**.

- The atomic mass of an element is called **molar mass of atoms** which is expressed in **grams** (g).
  If the atomic mass of carbon (C) equals 12 u, then one mole of carbon atom represents 12 g of it.
  So, the molar mass of carbon atoms = 12 g/mol

The element	The atomic mass	The molar mass
Hydrogen H	1 u	1 g/mol
Carbon C	12 u	12 g/mol
Nitrogen N	14 u	14 g/mol
Oxygen O	16 u	16 g/mol
Sodium Na	23 u	23 g/mol
Sulphur S	32 u	32 g/mol

- The molar mass of different elements are different. **GR.**
  ⟹ Because they have different atomic masses.

2 If the substance is in the form of molecules (the building unit of substance is molecule)

- The mass of one molecule is the sum of the atomic masses of the atoms forming that molecule.

EKB

Molecular mass

The sum of the atomic masses of the atoms forming the molecule.

- The mass of one mole of molecule is called **molar mass of molecules**, which is expressed in **grams (g)**.

Example

- Carbon dioxide molecule has a molecular formula CO_2
  ⟹ It consists of one carbon atom and two oxygen atoms.
  ⟹ Its molecular mass = (1 × atomic mass of C) + (2 × atomic mass of O)
  = (1 × 12) + (2 × 16) = 12 + 32 = 44 u
  ⟹ Its molar mass (the mass of one mole) = 44 g/mol

Note

1 atomic mass unit equals 1.66×10^{-24} gram.

Application

Calculate the molar mass of anhydrous copper sulphate $CuSO_4.5H_2O$

[Cu = 63.5 , S = 32 , O = 16 , H = 1]

$$CuSO_4.5H_2O$$

$$(63.5) + (32) + (4\times16) + (5\times2\times1) + (5\times16)$$

$$63.5 + 32 + 64 + 10 + 80 = 249.5 \text{ g/mol}$$

UNIT 2

- The mass of a mole differs from one matter to another. **GR.**

  ⇒ Due to the difference of matter in their molecular composition, therefore they differ in their molecular mass, as in the opposite table :

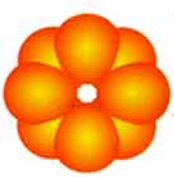
The element	The molar mass
Copper Cu	63.5 g/mol
Anhydrous copper sulphate $CuSO_4.5H_2O$	249.5 g/mol

- **The mole of a diatomic molecule of an element contains 2 moles of atoms, as in the following table :**

Element	Hydrogen	Nitrogen	Oxygen	Fluorine	Chlorine	Bromine	Iodine
Molar mass of atom	1 g/mol	14 g/mol	16 g/mol	19 g/mol	35.5 g/mol	80 g/mol	127 g/mol
Molecule of element	H_2 	N_2 	O_2 	F_2 	Cl_2 	Br_2 	I_2 
Molar mass of molecule	2 × 1 = 2 g/mol	2 × 14 = 28 g/mol	2 × 16 = 32 g/mol	2 × 19 = 38 g/mol	2 × 35.5 = 71 g/mol	2 × 80 = 160 g/mol	2 × 127 = 254 g/mol

- **There are some elements have different molecular formulas depending on their physical state.**

So, the mass of one mole will differ from one state to the other

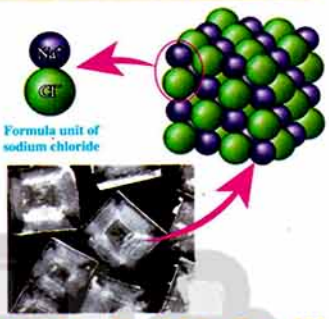
Element	Phosphorus		Sulphur	
Physical state	Vapor state	Solid state	Vapor state	Solid state
Building units	Each molecule consists of 4 atoms	Mono-atomic molecule	Each molecule consists of 8 atoms	Mono-atomic molecule
Molecular formula	P_4  	P 	S_8  	S 
Mass of one mole	4 × 31 = 124 g	31 g	8 × 32 = 256 g	32 g

Give reasons :

1. **The difference between the molar mass of phosphorus from solid state to vapor state.**
   Because of the difference between their molecular formula of the solid state and vapor state, according to the difference in the molecular mass.
2. **The molar mass of oxygen molecule differs from that of oxygen atom.**
   Because one mole of oxgyen molecule contains two moles of oxygen atoms, at which the oxygen is a diatomic molecule.

3 If the substance is in the form of ionic compound (the building unit of substance is formula unit)

1. The ionic compounds are found in the form of crystal lattice, as the ion is surrounded from all directions with the ions of an opposite charge.
2. The ionic compounds can be expressed by the **"Formula unit"**, which shows the ratio between the ions forming it.



Example 1

[Na = 23 , Cl = 35.5 , Ca = 40]

Ionic compound	Sodium chloride	Calcium chloride
Ratio between ions	$Na^+ : Cl^-$	$1Ca^{2+} : 2Cl^-$
Formula unit	NaCl	$CaCl_2$
Molar mass	23 + 35.5 = 58.5 g/mol	40 + (2 × 35.5) = 111 g/mol

Example 2

Calculate the molar mass for each of the following :

(1) Cl_2 (2) H_2O
(3) H_2SO_4 (4) Na_2CO_3

Cl	= 35.5
H	= 1
O	= 16
S	= 32
Na	= 23
C	= 12

Solution

(1) The molar mass of Cl_2 = 2 × 35.5 = 71 g/mol
(2) The molar mass of H_2O = (2 × 1) + 16 = 18 g/mol
(3) The molar mass of H_2SO_4 = (2 × 1) + 32 + (4 × 16) = 98 g/mol
(4) The molar mass of Na_2CO_3 = (2 × 23) + 12 + (3 × 16) = 106 g/mol

Note

In case we need to change the atomic mass, molecular mass or mass of formula unit into molar mass, we just change the unit from a.m.u (u) to g/mol without changing the value.

UNIT 2

The mole and Avogadro's number

EKB

* **Dozen** is a word that describes a quantity equals 12.

i.e. when we say a dozen of eggs, we mean 12 eggs or a dozen of balls, we mean 12 balls,...etc. **So,** dozen contains a constant number (12) of anything.

* Similarly, the word **mole** is also used to describe a constant number of (atoms, molecules, formula units or ions) of any substance, this number equals 6.02×10^{23} and it is called **"Avogadro's number"**.

Avogadro's number

It is the number of atoms, molecules, formula units or ions which are found in one mole of substance and it equals 6.02×10^{23} (atom, molecule or ion).

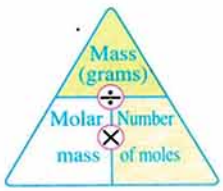
The mole

It is an amount of a substance that contains Avogadro's number of particles (molecules, atoms, ions or formula units).

We can illustrate the previous through the following table :

Substance	Chemical formula	Particles	No. of particles in one mole
Helium	He	Mono-atomic molecules	6.02×10^{23} helium molecules 6.02×10^{23} helium atoms
Oxygen	O_2	Diatomic molecules	6.02×10^{23} oxygen molecules $2 \times 6.02 \times 10^{23}$ oxygen atoms
Water	H_2O	Molecules	6.02×10^{23} water molecules $2 \times 6.02 \times 10^{23}$ hydrogen atoms 6.02×10^{23} oxygen atoms
Calcium chloride	$CaCl_2$	Formula units	6.02×10^{23} $CaCl_2$ formula units 6.02×10^{23} calcium ions $2 \times 6.02 \times 10^{23}$ chloride ions

Calculation the number of moles



- We can calculate the number of moles by using the following relation :

$$\text{Number of moles (mol)} = \frac{\text{Mass of substance (g)}}{\text{Molar mass (mass of one mole) (g/mol)}}$$

- We can calculate the number of molecules, atoms or ions in the substance by using the following relation :

$$\text{No. of } \begin{cases} \text{molecules} \\ \text{atoms} \\ \text{formula units} \\ \text{ions} \end{cases} = \text{no. of moles of } \begin{cases} \text{molecules} \\ \text{atoms} \\ \text{formula units} \\ \text{ions} \end{cases} \times 6.02 \times 10^{23}$$

Examples

1 How many moles are present in 191 grams of copper ? [Cu = 63.5]

Solution

- Atomic mass of copper = 63.5 amu
- The molar mass = 63.5 g/mol
- The no. of moles of copper = $\frac{191 \text{ g}}{63.5 \text{ g/mol}} = 3$ mol

2 Calculate the number of moles of water found in 36 g of it. [H = 1 , O = 16]

Solution

- The molar mass of $H_2O = 16 + (1 \times 2) = 18$ g/mol
- The number of moles of water = $\frac{36}{18} = 2$ mol

3 Calculate the mass of 0.5 mole of sulphuric acid (H_2SO_4). [H = 1 , S = 32 , O = 16]

Solution

- The molecular mass of $H_2SO_4 = (2 \times 1) + 32 + (4 \times 16) = 98$ u
- The molar mass = 98 g/mol
- The mass of 0.5 mole of H_2SO_4 = no. of moles × molar mass
  $= 0.5 \text{ mol} \times 98 \text{ g/mol} = 49 \text{ g}$

4 Calculate the number of molecules that are found in a sample of sulphur dioxide of mass 32 g. [S = 32, O = 16]

Solution

- The molar mass of $SO_2 = 32 + (2 \times 16) = 64$ g/mol
- The number of moles of $SO_2 = \frac{32}{64} = 0.5$ mol
- The number of molecules of $SO_2 = 0.5 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ molecules

UNIT 2

5 **Calculate the number of carbon atoms found in 50 g of calcium carbonate.**

[Ca = 40 , C = 12 , O = 16]

Solution

- Molar mass of $CaCO_3 = 40 + 12 + (3 \times 16) = 100$ g/mol
- No. of moles of $CaCO_3 = \frac{\text{mass}}{\text{molar mass}} = \frac{50 \text{ g}}{100 \text{ g/mol}} = 0.5$ mol

1 mol $CaCO_3 \longrightarrow 6.02 \times 10^{23}$ carbon atoms

0.5 mol $CaCO_3 \longrightarrow$ X carbon atoms

- No. of carbon atoms (X) $= 0.5 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ atoms.

6 **Calculate the number of sodium ions found in 0.212 mol of sodium carbonate Na_2CO_3**

Solution

$$Na_2CO_3 \longrightarrow 2Na^+ + CO_3^{2-}$$

1 mol 2 mol

0.212 mol ? mol

$\therefore$ No. of moles of $Na^+ = \frac{2 \times 0.212}{1} = 0.424$ mol

$\therefore$ No. of Na^+ ions $= 0.424 \times 6.02 \times 10^{23} = 2.55 \times 10^{23}$ ions.

7 **Zinc reacts with vapor sulphur, according to the following reaction :**

$$8Zn_{(s)} + S_{8(g)} \longrightarrow 8ZnS_{(s)}$$

Calculate the mass of zinc sulphide ZnS, which is resulted from the reaction of 32 g of sulphur with an excess amount of zinc. [Zn = 65 , S = 32]

Solution

$S_{8(g)}$ produces $8ZnS_{(s)}$

$(8 \times 32) = 256$ g $8 \times (65 + 32) = 776$ g

32 g ? g

$\therefore$ The mass of zinc sulphide $= \frac{776 \times 32}{256} = 97$ g

8 **Iron (III) oxide reacts with aluminum, according to the following reaction :**

$$2Al_{(s)} + Fe_2O_{3(s)} \xrightarrow{\Delta} Al_2O_{3(s)} + 2Fe_{(l)}$$

(A) Calculate the mass of Al_2O_3, which is resulted from the reaction of 1.42×10^{24} atoms of Al with an excess amount of Fe_2O_3

(B) What is the number of the formula units of Fe_2O_3, which is required for the reaction with 0.134 g of Al ? [Al = 27 , O = 16 , Fe = 56]

Solution

(A) No. of moles of Al atoms = $\frac{1.42 \times 10^{24}}{6.02 \times 10^{23}} = 2.359$ mol

$\therefore$ Mass of Al = $27 \times 2.359 = 63.69$ g

$2Al_{(s)} \xrightarrow{\text{produce}} Al_2O_{3(s)}$

$2 \times 27 = 54$ g $\quad$ $(2 \times 27) + (3 \times 16) = 102$ g

63.69 g $\quad$? g

$\therefore$ The mass of resulted $Al_2O_3 = \frac{102 \times 63.69}{54} = 120.3$ g

(B) $2Al_{(s)} \xrightarrow{\text{react with}} Fe_2O_{3(s)}$

$2 \times 27 = 54$ g $\quad$ $(2 \times 56) + (3 \times 16) = 160$ g

0.134 g $\quad$? g

$\therefore$ Mass of $Fe_2O_3 = \frac{0.134 \times 160}{54} = 0.397$ g

$\therefore$ No. of moles of $Fe_2O_3 = \frac{0.397}{160} = 0.0025$ mol

$\therefore$ No. of formula units of $Fe_2O_3 = 6.02 \times 10^{23} \times 0.0025 = 1.5 \times 10^{21}$ formula unit.

9 Calculate the mass of one molecule of chlorine gas by the following units :

(A) Atomic mass unit (u). (B) Gram (g).

Solution

(A) Mass of one molecule of chlorine gas = $2 \times 35.5 = 71$ u

(B) $\because$ One mole of Cl_2 contains 6.02×10^{23} molecules

$\therefore$ Mass of 6.02×10^{23} molecule of Cl_2 = Molar mass = 71 g/mol

$\therefore$ Mass of one molecule of $Cl_2 = \frac{71}{6.02 \times 10^{23}} = 1.1788 \times 10^{-22}$ g

10 Calculate by using meter unit, the length of the line formed from arranging of carbon atoms together, which are present in a sample of 0.12 g. Knowing that the radius of carbon atom is 0.7 nm.

UNIT 2

Solution

No. of moles of carbon atoms = $\frac{0.12}{12} = 0.01$ mol

No. of C atoms = $0.01 \times 6.02 \times 10^{23} = 6.02 \times 10^{21}$ atom

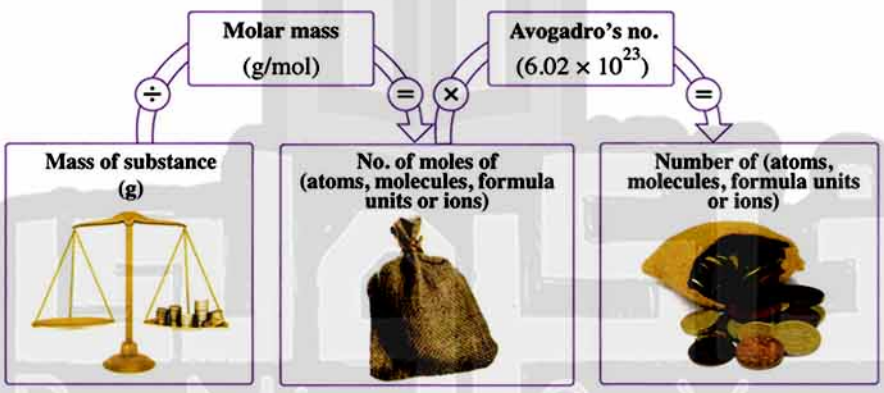
Diameter of carbon atom = $0.7 \times 10^{-9} = 7 \times 10^{-10}$ m

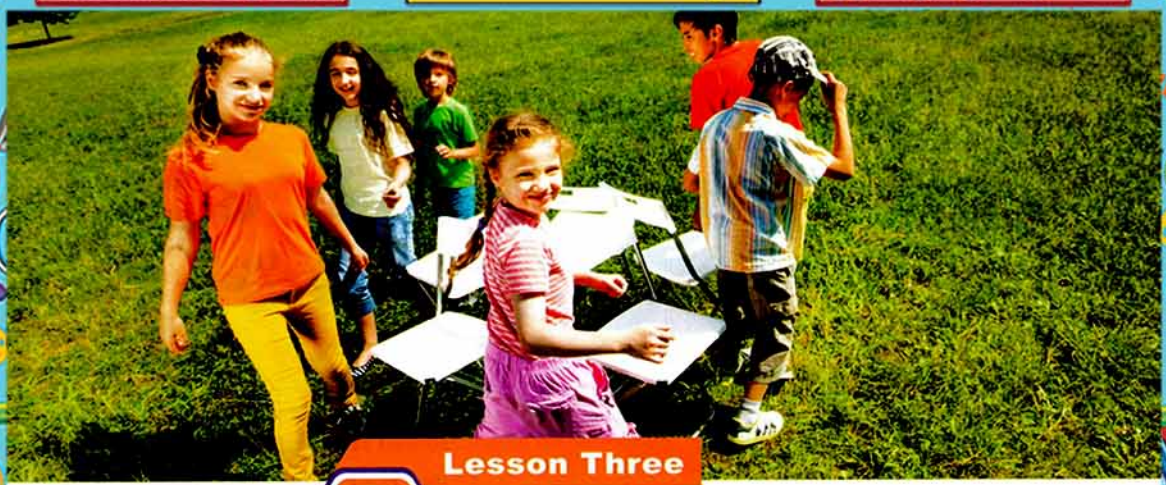
Length of the line = No. of C atoms × diameter of C atom

$= 7 \times 10^{-10} \times 6.02 \times 10^{21}$

$= 4.214 \times 10^{12}$ m

☆ **All the previous calculations can be summarized as the following :**





Lesson Three

Chapter 1

The Limiting Reactant of the Chemical Reaction

- Every chemical reaction needs accurately calculated amounts of reactants to obtain the required amounts of products.
- If the amount of one of the reactants increases than required, **this extra amount** remains as it is, without participation in the reaction.
- The other reactant is **completely consumed** and determines the quantities of products formed and it is called **"The limiting reactant"**.

The limiting reactant

The reactant which is completely consumed during the chemical reaction and reacts with other reactants to produce the lowest number of moles of the product.

Example

Reaction between methane gas and water vapor to produce water gas fuel (H_2 / CO).

$$CH_{4(g)} + H_2O_{(g)} \longrightarrow 3H_{2(g)} + CO_{(g)}$$

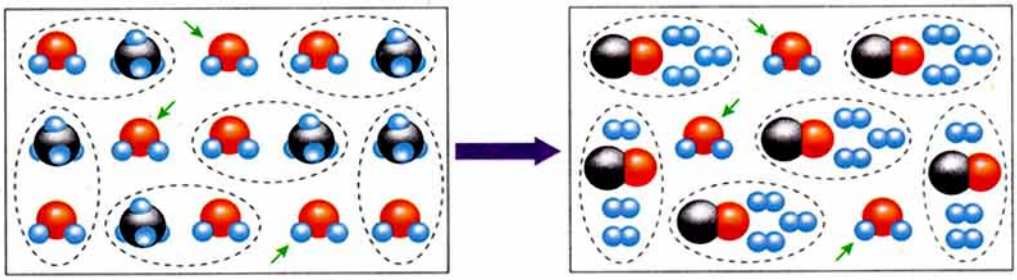
From the previous reaction :

⇒ 1 mol of CH_4 reacted with 1 mol of H_2O

What happens if 6 mol of CH_4 is added to 9 mol of H_2O ?

⇒ 6 mol of CH_4 will react with 6 mol of H_2O and 3 mol of H_2O are remaining without any reaction, therefore CH_4 is the limiting reactant.

UNIT 2



6 mol CH_4 + 9 mol H_2O

18 mol H_2 + 6 mol CO +
(3 mol H_2O without reaction)

Examples

1 In the following reaction :

$$P_{4(v)} + 5O_{2(g)} \longrightarrow P_4O_{10(s)}$$

If 0.4 mol of O_2 gas is passed through 0.008 mol of P_4 what is the limiting reactant ?

Solution

$5O_{2(g)}$	$\longrightarrow$	$P_4O_{10(s)}$
5 mol		1 mol
0.4 mol		? mol

Number of moles of P_4O_{10} produced
$= \frac{0.4 \times 1}{5} = 0.08$ mol

$P_{4(v)}$	$\longrightarrow$	$P_4O_{10(s)}$
1 mol		1 mol
0.008 mol		? mol

Number of moles of P_4O_{10} produced
$= 0.008 \times 1 = 0.008$ mol

The number of moles of P_4O_{10} produced according to the quantity of P_4 is lower than that produced from O_2

$\therefore$ P_4 is the limiting reactant.

2 Magnesium reacted with oxygen gas as the following equation :

$$2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)} \qquad [Mg = 24 , O = 16]$$

What is the limiting reactant ? What is the mass of remaining reactants in each case of the following :

A 16 g of O_2 added to 48 g of Mg

B 32 g of O_2 added to 12 g of Mg

Solution

A

No. of moles of $O_2 = \frac{16}{32} = 0.5$ mol

$O_{2(g)}$	⟶	$2MgO_{(s)}$
1 mol		2 mol
0.5 mol		? mol

No. of moles of MgO $= \frac{2 \times 0.5}{1} = 1$ mol

No. of moles of Mg $= \frac{48}{24} = 2$ mol

$2Mg_{(s)}$	⟶	$2MgO_{(s)}$
2 mol		2 mol
2 mol		? mol

No. of moles of MgO $= \frac{2 \times 2}{2} = 2$ mol

The number of moles of MgO which is produced, according to the quantity of O_2 is lower than that produced from Mg

∴ The limiting reactant is O_2

To calculate the remaining mass of Mg :

$2Mg_{(s)}$	reacts with	$O_{2(g)}$
$(2 \times 24) = 48$ g		$(2 \times 16) = 32$ g
? g		16 g

The reacted mass of Mg $= \frac{16 \times 48}{32} = 24$ g

The remaining mass of Mg $= 48 - 24 = 24$ g

B

The no. of moles of Mg $= \frac{12}{24} = 0.5$ mol

$2Mg_{(s)}$	⟶	$2MgO_{(s)}$
2 mol		2 mol
0.5 mol		? mol

No. of moles of MgO $= \frac{2 \times 0.5}{2} = 0.5$ mol

The no. of moles of $O_2 = \frac{32}{32} = 1$ mol

$O_{2(g)}$	⟶	$2MgO_{(s)}$
1 mol		2 mol
1 mol		? mol

No. of moles of MgO $= 2 \times 1 = 2$ mol

The number of moles of MgO which is produced, according to the quantity of Mg is lower than that produced from O_2

∴ The limiting reactant is Mg

To calculate the remaining mass of O_2 :

$2Mg_{(s)}$	reacts with	$O_{2(g)}$
48 g		32 g
12 g		? g

The reacted mass of $O_2 = \frac{12 \times 32}{48} = 8$ g

The remaining mass of $O_2 = 32 - 8 = 24$ g

UNIT 2

The mole and volume of gases

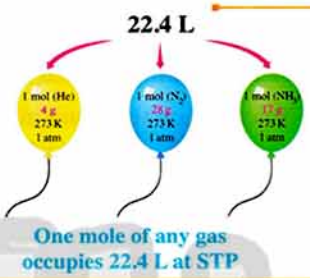
- The solid or liquid matter has a definite and constant volume. It can be measured by various methods. On the other hand, the volume of gases changes according to the volume of the container.

Avogadro's Law

Gas volume is directly proportional to the number of its moles when the temperature and pressure are constant.

Avogadro's postulate

Equal volumes of different gases contain an equal number of molecules, at the same standard temperature and pressure (STP).



Note

STP means Standard Temperature and Pressure that means temperature = 273 K which equals 0°C and pressure = 760 mm.Hg which equals the normal atmospheric pressure (1 atm pressure).

Molar volume :

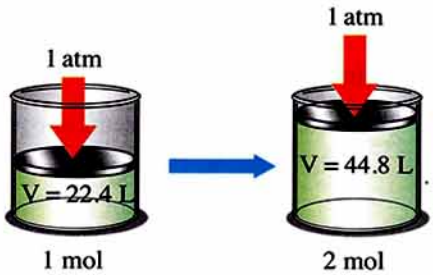
The volume of one mole of any gas = 22.4 L at STP

The following table illustrates the relation among number of the gas moles, its volume and the number of its molecules, at STP :

Gas:	 He	 N_2	 NH_3	 CH_4
Molar mass:	4 g/mol	28 g/mol	17 g/mol	16 g/mol
No. of moles:	1 mol			
Gas volume:	22.4 L			
No. of molecules:	6.02×10^{23} molecules			

This means that

- One mole from any gas at STP occupies a volume of 22.4 L
- One mole from any gas contains 6.02×10^{23} molecules.
- If the number of moles is doubled, the volume doubled and the number of molecules also doubled.



Example

Reaction of hydrogen gas with chlorine gas to give hydrogen chloride gas.

$$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$$

1 : 1 : 2

1 volume of H_2 — 22.4 L — 6.02×10^{23} molecule

1 volume of Cl_2 — 22.4 L — 6.02×10^{23} molecule

2 volumes of HCl — 44.8 L — $2 \times 6.02 \times 10^{23}$ molecule

- One volume of H_2 gas reacts with one volume of Cl_2 to give 2 volumes of HCl gas.
- If 2 volumes of H_2 gas reacted with one volume of Cl_2 gas, 2 volumes of HCl are formed and one volume of H_2 gas is remaining.

2 volumes of H_2 — 44.8 L

1 volume of Cl_2 — 22.4 L

2 volumes of HCl — 44.8 L

- **We can calculate the volume of any gas at STP as follows :**

Volume of gas (at STP) = no. of moles × 22.4 L

Examples

1 Calculate the volume of 8 g of oxygen gas at STP. [O = 16]

Solution

Molar mass of O_2 gas = 16 + 16 = 32 g/mol

$$\text{No. of moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{8}{32} = 0.25 \text{ mol}$$

Volume of O_2 gas = no. of moles × 22.4 = 0.25 × 22.4 = 5.6 L

UNIT 2

2 Calculate the volume of oxygen needed to produce 90 g of water by reacting with an excess amount of hydrogen at STP. [O = 16 , H = 1]

Solution

Write the balanced chemical equation :

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

1 mol — 2 mol

1 × 22.4 L — 2 (2 × 1 + 16) = 2 × 18 = 36 g

? L — 90 g

$$\therefore \text{Volume of oxygen} = \frac{90 \text{ g} \times 22.4 \text{ L}}{36 \text{ g}} = 56 \text{ L}$$

3 Calculate the mass of $CaCO_3$ required to produce 5.1 L of CO_2 gas at STP.

According to the following equation :

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)}\uparrow + H_2O_{(l)}$$

[$CaCO_3$ = 100 g/mol , CO_2 = 44 g/mol]

Solution

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)}\uparrow + H_2O_{(l)}$$

1 mol — 1 mol

100 g — 22.4 L

? g — 5.1 L

$$\text{Mass of } CaCO_3 = \frac{5.1 \text{ L} \times 100 \text{ g}}{22.4 \text{ L}} = 22.76 \text{ g}$$

• We can illustrate the previous expressions through the following table :

The chemical reaction	$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$
No. of moles	1 mol + 3 mol ⟶ 2 mol
Mass	$1 \times (2 \times 14) + 3 \times (2 \times 1) \longrightarrow 2 \times [14 + (3 \times 1)]$ 28 g (N_2) + 6 g (H_2) ⟶ 34 g (NH_3)
No. of molecules	$1 \times 6.02 \times 10^{23}$ (N_2) + $3 \times 6.02 \times 10^{23}$ (H_2) ⟶ $2 \times 6.02 \times 10^{23}$ (NH_3) molecules molecules molecules
Volume (at STP)	1 × 22.4 L (N_2 gas) + 3 × 22.4 L (H_2 gas) ⟶ 2 × 22.4 L (NH_3 gas)

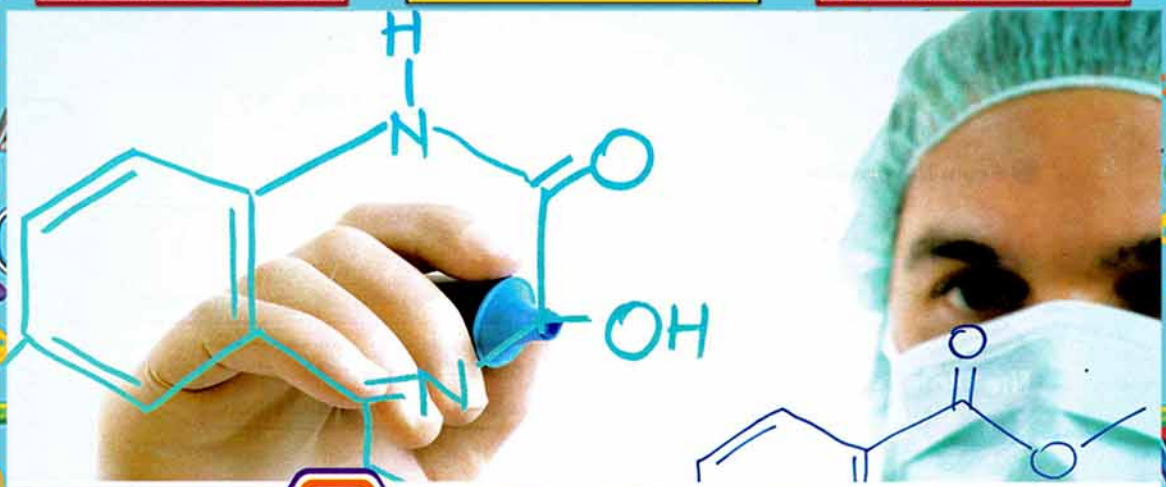
From the previous, we can conclude that :

The Mole

Mass :
- Molar mass of atom or ion expressed in grams.
- Molar mass of molecule or formula unit expressed in grams.

Number of particles (Avogadro's number) :
6.02×10^{23} of molecules, atoms, ions or formula units.

Volume :
22.4 L of gas at STP



Chapter 2 Calculation of the Chemical Formula

- **The chemical compound** is made up of units called **molecules** or **formula units** which consist of **atoms** or **ions** of two or more elements.
- **The chemical compound** is represented by **a chemical formula** which is a simple symbolic formula that indicates :
  - The elements percentage.
  - The number of atoms or ions of each element.

The chemical compound	Type	Building units	Chemical formula	Each unit
Water	Covalent	Molecules	H_2O	Each molecule consists of one atom of O and two atoms of H
Calcium bromide	Ionic	Formula unit	$CaBr_2$	Each formula unit consists of one calcium ion (Ca^{2+}) and two bromide ions (Br^-).

Types of chemical formulas

- The empirical formula
- The molecular formula
- The structural formula

1 The empirical formula

The empirical formula

It is a symbolic chemical formula which represents the simplest whole number ratio of the atoms of elements in a compound.

Application

- HO is the empirical formula for H_2O_2
- P_2O_5 is the empirical formula for P_4O_{10}
- CH_2O is the empirical formula for CH_2O , $C_2H_4O_2$, $C_6H_{12}O_6$

Note

The empirical formula doesn't represent the actual composition of the molecule or the formula unit.

2 The molecular formula

The molecular formula

It is a symbolic chemical formula which represents the type and the real number of atoms or ions in a molecule or the formula unit of a compound.

Application

The compound	Empirical formula	Molecular formula
Propylene	CH_2	C_3H_6
Acetic acid	CH_2O	$C_2H_4O_2$
Formaldehyde	CH_2O	CH_2O

Notes

1. In most cases the **molecular formula** is a multiple of the **empirical formula**.
2. In some cases the empirical and molecular formulas are identical such as : carbon dioxide CO_2, nitric oxide NO and formaldehyde CH_2O
3. In some cases many compounds may have the same empirical formula such as : acetylene C_2H_2 and benzene C_6H_6 have the same empirical formula (CH).

Calculating the percentage of the components of a compound

We use the expression of "**the mass percentage**" to calculate the ratio of each component in a certain compound.

The mass percentage :

The number of units from the particle for each 100 units from the overall.

UNIT 2

1 Calculating the percentage of an element from a chemical formula

The following equation shows how the percentage of an element in a compound is calculated.

$$\% \text{ of element} = \frac{\text{The mass of element in one mole of compound}}{\text{Molar mass of compound}} \times 100\%$$

Examples

1 Calculate the mass percentages of N, H and O in ammonium nitrate NH_4NO_3 [H = 1 , N = 14 , O = 16]

Solution

NH_4NO_3 contains $2N + 4H + 3O$

$[14 + (4 \times 1) + 14 + (3 \times 16)]$g (2×14)g (4×1)g (3×16)g

80 g 28 g 4 g 48 g

$$\% \text{ of N} = \frac{28}{80} \times 100\% = 35\% \qquad \% \text{ of H} = \frac{4}{80} \times 100\% = 5\%$$

$$\% \text{ of O} = \frac{48}{80} \times 100\% = 60\%$$

- The sum of the percentages of elements in a compound must be 100%

% of N + % of H + % of O = 100%

35% + 5% + 60% = 100%

2 Calculate the mass percentages of Fe and O in iron (III) oxide. [Fe = 56 , O = 16]

Solution

Molar mass of $Fe_2O_3 = (2 \times 56) + (3 \times 16) = 160$ g

$$\% \text{ of Fe} = \frac{2 \times 56}{160} \times 100\% = 70\% \qquad \% \text{ of O} = \frac{3 \times 16}{160} \times 100\% = 30\%$$

Note

We can calculate the mass of an element in one mole of the compound as follows :

$$\text{Mass of an element in one mole of the compound} = \frac{\text{It's percentage} \times \text{Molar mass of the compound}}{100\%}$$

3 Calculate mass of iron present in 500 kg of an impure sample of hematite ore Fe_2O_3, knowing that mass percentage of iron in that sample is 58 %

Solution

$$\text{Mass of element in the sample} = \frac{\text{Mass percentage} \times \text{Mass of sample}}{100\ \%}$$

$$= \frac{58\ \% \times 500}{100\ \%} = 290 \text{ kg}$$

4 Calculate the number of moles of carbon and hydrogen atoms in a hydrocarbon compound containing 85.71% of carbon and its molar mass is 28 g/mol.

[C = 12 , H = 1]

Solution

- **Hydrocarbon** means that compound is containing only C and H

$\therefore$ % of H = 100 – 85.71% = 14.29%

$$\text{Mass of C in one mole of a compound} = \frac{85.71\% \times 28}{100\%} = 24 \text{ g}$$

$$\therefore \text{ The number of moles of C atoms} = \frac{24}{12} = 2 \text{ mol}$$

$$\text{Mass of H in one mole of a compound} = \frac{14.29\% \times 28}{100\%} = 4 \text{ g}$$

$$\therefore \text{ The number of moles of H atoms} = \frac{4}{1} = 4 \text{ mol}$$

2 Calculating the percentage of an element from the practical results :

The percentage of an element can be calculated from the experimental results as follows :

$$\text{\% of element} = \frac{\text{Mass of element in the sample}}{\text{Total mass of the sample}} \times 100\%$$

Example

A sample of 14.2 g mercury (II) oxide is chemically decomposed into 13.2 g of mercury. What is the percentages of Hg and O in this compound ?

Solution

$$\text{\% of Hg} = \frac{\text{mass of Hg}}{\text{mass of the sample}} \times 100\% = \frac{13.2}{14.2} \times 100\% = 93\%$$

% of Hg + % of O = 100% $\qquad$ % of O = 100% – 93% = 7%

Calculating the empirical and molecular formulas from the percentages of elements

Preface Example

Chemical analysis has proven that acetic acid is formed from 40% of C, 6.67% of H and 53.33% of O and its molar mass is 60 g/mol. What are the empirical and molecular formulas of this acid ? [H = 1 , C = 12 , O = 16]

Solution

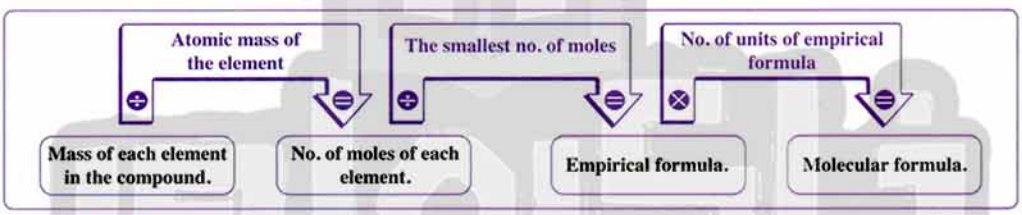
40% of C, 6.67% of H and 53.33% of O indicate that each 100 g from the compound contain 40 g of carbon, 6.67 g of hydrogen and 53.33 g of oxygen.

Steps	Solution of the example		
	C	H	O
❶ **Calculate the no. of moles for each element:** No.of moles = $\frac{\text{Mass of element}}{\text{Atomic mass of element}}$	$\frac{40}{12} = 3.33$	$\frac{6.67}{1} = 6.67$	$\frac{53.33}{16} = 3.33$

UNIT 2

❷ Calculate the mole ratio for each element: Mole ratio = No. of moles of element / The smallest no. of moles	$\frac{3.33}{3.33} = 1$	$\frac{6.67}{3.33} = 2$	$\frac{3.33}{3.33} = 1$
❸ You can calculate the empirical formula	The empirical formula is CH_2O		
❹ Calculate the no. of units of the empirical formula = Molar mass of the compound / Mass of the empirical formula	Molar mass of the empirical formula $= C + 2H + O = 12 + (2 \times 1) + 16 = 30$ g No. of units of the empirical formula (n) $= \frac{60}{30} = 2$		
❺ Calculate the molecular formula: The molecular formula = Empirical formula × No. of units of the empirical formula (n).	The molecular formula $= (CH_2O) \times 2$ $= C_2H_4O_2$		

You can summarize the previous steps in the following :



Examples

❶ Calculate the molecular formula for water which contains 11.19% H and 88.81% O, knowing that its molar mass is 18 g/mol. [H=1 , O=16]

Solution

Each 100 g from the compound contains 11.19 g of H and 88.81 g of O

Elements	H	O
No. of moles =	$\frac{11.19}{1} = 11.19$	$\frac{88.81}{16} = 5.551$
Mole ratio =	$\frac{11.19}{5.551} = 2$	$\frac{5.551}{5.551} = 1$
	2 : 1	
∴ The empirical formula	H_2O	
∴ Molar mass of empirical formula	$2 \times 1 + 16 = 18$ g/mol	
∴ No. of units of empirical formula	$\frac{18}{18} = 1$	
∴ The molecular formula of water	H_2O	

❷ **Calculate the molecular formula for a compound containing 25.9% of N and 74.1% of O, knowing that its molar mass equals 108 g/mol.** [N = 14 , O = 16]

Solution

Each 100 g from the compound contains 25.9 g of N and 74.1 g of O

Element	N	O
No. of moles =	$\frac{25.9}{14} = 1.85$	$\frac{74.1}{16} = 4.63$
Mole ratio =	$\frac{1.85}{1.85} = 1$	$\frac{4.63}{1.85} = 2.5$
Multiply by 2 to obtain whole numbers.	2	5
∴ The empirical formula	N_2O_5	
∴ Molar mass of empirical formula	$(2 \times 14) + (5 \times 16) = 108$ g/mol	
∴ No. of units of empirical formula	$n = \frac{108}{108} = 1$	

∴ **The molecular formula is N_2O_5**

Give reasons :

❶ **The molecular formula and the empirical formula for each of carbon monoxide CO and nitric oxide NO are the same.**

Because the molar mass of the empirical formula equals the molar mass of the molecular formula.

❷ **In most cases the empirical formula can't represent the chemical structure of a compound.**

Because the empirical formula doesn't represent the actual number of atoms, ions or formula units which form the molecule of the compound.

❸ **Both of actylene C_2H_2 and benzene C_6H_6 have the same empirical formula CH, but they differ in the molecular formula.**

They have the same empirical formula because they have the same ratio of elements forming both of them (1 : 1).

But, they differ in the molecular formula because of the difference in their molecular mass and also number of units of the empirical formula.

Theoretical yield, practical yield and percentage of yield

The theoretical yield of the reaction

It is the calculated quantity of product expected from given quantities of reactants.

The practical yield of the reaction

It is the quantity of product that is actually produced from the chemical reaction.

UNIT 2

$$\text{The percentage of yield} = \frac{\text{Practical yield}}{\text{Theoretical yield}} \times 100\%$$

- **In most reactions** the **practical yield** is less than the **theoretical yield** and the **percentage of yield** is less than 100%
- **Reasons of reducing in yield :**
  1. Some of product may clink-on (stick) to the walls of the reactions cylinder.
  2. The reactants are not pure enough.
  3. The participation of the reactants in other reactions which are called side reactions.
  4. The product is volatile (easily evaporated).

Example 1 **Methyl alcohol is produced through the following reaction :**

$$CO_{(g)} + 2H_{2(g)} \xrightarrow{\Delta} CH_3OH_{(l)}$$

If 6.1 g of methyl alcohol is produced from the reaction of 1.2 g of H_2 with an excess amount of carbon monoxide. Calculate the percentage of yield. [C = 12 , O = 16 , H = 1]

Solution

$CO_{(g)}$ + $2H_{2(g)}$ ⟶ $CH_3OH_{(l)}$

2 mol — 1 mol

$2(2 \times 1) = 4$ g — $12 + (4 \times 1) + 16 = 32$

1.2 g — ? g

$$\text{Theoretical yield} = \frac{1.2 \times 32}{4} = 9.6 \text{ g}$$

$$\text{Percentage of yield} = \frac{6.1}{9.6} \times 100\% = 63.54\%$$

Molecule of methyl alcohol CH_3OH

Example 2

Calculate the percentage of yield for a reaction between 20 g of sodium chloride solution with an excess amount of silver nitrate, if 45 g of AgCl is precipitated from this reaction.

[Na = 23 , Cl = 35.5 , Ag = 108]

Solution

$NaCl_{(aq)}$ + $AgNO_{3(aq)}$ ⟶ $NaNO_{3(aq)}$ + $AgCl_{(s)}\downarrow$

$(23 + 35.5)$ g — $(108 + 35.5)$ g

58.5 g — 143.5 g

20 g — ? g

$$\text{Theoretical yield} = \frac{20 \times 143.5}{58.5} = 49.06 \text{ g}$$

$$\text{Percentage of yield} = \frac{45}{49.06} \times 100\% = 91.72\%$$

White gelatinous ppt. of silver chloride

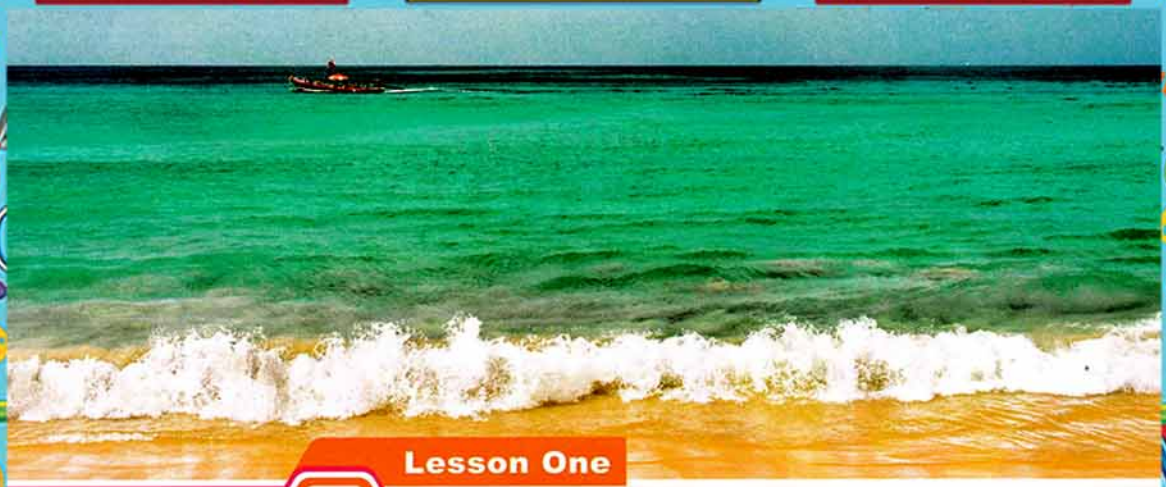
Solutions, Acids & Bases

UNIT 3

Unit Objectives

By the end of this unit, the student will be able to :

- Explain what is meant by solution and distinguish between the types of solutions by practical experiments.
- Describe the solubility process, the factors affecting it and the heat changes accomplished with it.
- Show the concentration of solutions using different methods.
- Calculate the concentration of the solution using one of the concentration units.
- Identify the general properties of solutions "solid in a liquid".
- Represent the graphical relationship between concentration of the solution, the vapor pressure, the change in its boiling and freezing point.
- Compare between the colloid solutions and the real solutions in terms of the size of their compositions.
- Prepare some simple colloids and show their importance in our everyday life.
- Explain what is meant by an acid and a base and their classifications.
- Compare between the different theories to define the acid and the base.
- Distinguish between acids and bases using indicators and the pH-meter.
- Understand how salts form, their naming and the pH values of their solutions.



Lesson One

Chapter 1 Mixtures and Concentration of Solutions

- **Mixture** means the thing which contains two or more different substances in any ratio such as seawater, granite and gasoline.
- The mixtures can be classified according to their homogeneity into two types :

Types of Mixtures

- **Homogeneous** → Solutions
- **Heterogeneous** → Colloids, Suspensions

☆ **The table shows the difference between these types :**

Solutions	Colloids	Suspensions
Their components can't be distinguished by the naked eye or the electron microscope.	Their components can be distinguished by the electron microscope only.	Their components can be distinguished by the naked eye.
Examples	**Examples**	**Examples**
- Table salt solution in water. - Cane - sugar solution in water. - Cobalt (II) chloride solution in water.	- Aerosols. - Hair gel. - Mayonnaise emulsion. - Blood. - Milk.	- Table salt in kerosene. - Cane - sugar in kerosene. - Cobalt (II) chloride in kerosene. - Oil in water.
 Cobalt (II) chloride $CoCl_2$ solution	 Milk	 Water - oil suspension

Homogeneous mixtures

Solutions

- If you add a small quantity of a substance (as sugar) to a large amount of another substance (as water) and disappears in it.

Therefore:

- Sugar is a **solute**.
- Water is a **solvent**.
- The produced mixture is a **solution**.

Solute
The minor component that has the lesser ratio in the solution.

⊕

Solvent
The major component that has the larger ratio in the solution.

⇒

Solution
It is a homogeneous mixture of two or more substances which are chemically unreacted.

Solute + Solvent → Solution

Give reason :

The sweet taste of the sugar solution in water is the same in all of its parts.

Because of the homogeneity of the sugar solution, as each part of the solution contains the same amount (concentration) of sugar.

- Solutions are necessary in the biological processes that occur inside the living organisms.

Types of Solutions

Solutions can be classified according to :

1. The physical state of the solvent.
2. The ability to conduct electricity.
3. The degree of saturation.

UNIT 3

1 According to the physical state of the solvent

The solutions are divided into

A Gaseous solutions. B Liquid solutions. C Solid solutions.

☆ **The following table shows some examples of these different types.**

Types of solution	Solute	Solvent	Examples
A Gaseous solutions	Gas	Gas	Atmospheric air - natural gas.
B Liquid solutions	Gas	Liquid	Soft drinks - oxygen dissolved in water.
	Liquid	Liquid	Alcohol in water - ethylene glycol (antifreeze) in water.
	Solid	Liquid	Sugar or salt in water.
C Solid solutions	Gas	Solid	Hydrogen gas on palladium or platinum.
	Liquid	Solid	Liquid mercury dissolved in solid silver (silver amalgam) $Hg_{(l)}/Ag_{(s)}$
	Solid	Solid	Alloys such as nickel-chrome alloy.

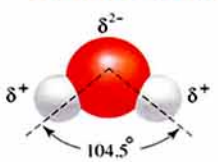
Scientific background knowledge

- **Electronegativity :** it is the ability of an atom to attract the electrons of the bond to itself.
- **Polar bond :** it is the covalent bond between two atoms which are different in electronegativity.
  [The higher electronegative atom carries a partial negative charge (δ^-), while the other atom carries a partial positive charge (δ^+)]

- **Polar molecules :** they are the molecules that have an end carring a partial positive charge (δ^+) and another end carrying a partial negative charge (δ^-).
- **Polar compound :** it is the compound which has a polar covalent bond.

Polar HCl molecule

- **The degree of polarity depends on :**
  - Difference in electronegativity between the bonded atoms.
  - Geometry of the molecule.
  - Bond angles.



Water H_2O polar molecule

Water is considered as a famous polar solvent. GR.

This polarity attributed to the following :

- The presence of two polar bonds.
  (Because the electronegativity of oxygen is higher than that of hydrogen).
- The structure of water molecule as shown in figure.
- Large bond angle = 104.5°

2 According to the ability to conduct electricity

Solutions of substances are divided into two types according to the ability to conduct electricity.

Solutions are divided into

A Solutions of electrolytes

- Solutions of substances that are ionized or dissociated, when dissolving in water.
- These solutions contain free ions. So, they conduct electricity.
  e.g: table salt soultion.

B Solutions of non-electrolytes

- Solutions of substances that aren't ionized or dissociated, when dissolving in water.
- These solutions don't contain free ions. So, they don't conduct electricity.
  e.g: sugar solution.

A Electrolytes

Electrolytes

They are substances in which their solutions or moltens can conduct electricity by the free ions movement.

Electrolytes are divided into :

Strong electrolytes

Conduct electricity to a great extent

Strong electrolytes

They are substances which are completely ionized and strongly conduct electricity.

e.g :

1. **Ionic compounds like :** Sodium chloride NaCl and sodium hydroxide NaOH, which are completely dissociated into ions when they dissolve in water.
2. **Polar covalent compounds like :** Hydrogen chloride HCl, which is completely ionized when it dissolves in water.

Weak electrolytes

Conduct electricity to a weak extent

Weak electrolytes

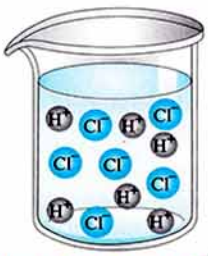
They are substances which are partially ionized and weakly conduct electricity.

e.g :

1. **Ionic compounds like :** Ammonium hydroxide NH_4OH, which is partially dissociated into ions when it dissolves in water.
2. **Polar covalent compounds like :** Acetic acid CH_3COOH, which is partially ionized when it dissolves in water.

UNIT 3

$HCl_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$



Hydrochloric acid is completely ionized

$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$

Acetic acid is partially ionized

? Compare between $HCl_{(g)}$ gas and $HCl_{(aq)}$ aqueous solution "according to conducting electricity".

$HCl_{(g)}$ is a bad conductor of electricity, because gases generally are non-conductors.

$HCl_{(aq)}$ is a good conductor of electricity, because it is a strong electrolyte.

Give reason :

- **Free protons H^+ ions can't exist as free ions in aqueous solutions of acids.**
- **Dissolution of $HCl_{(g)}$ in water can be expressed in this chemical equation :**

$H_2O_{(l)} + HCl_{(g)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$

Due to bonding of H^+ ions with the water molecules to form hydronium ion $H_3O^+_{(aq)}$

$H_2O_{(l)} + H^+_{(aq)} \longrightarrow H_3O^+_{(aq)}$

B Non-electrolytes

Non-electrolytes

They are the substances in which their solutions or moltens can't conduct electricity, as they have no free ions or hydrated ions.

Non-electrolytes don't conduct electricity

Example

- Ethyl alcohol.
- Sugar solution.

Give reason :

Ethyl alcohol is one of the non-electrolytes.

Because it is non-ionized and doesn't conduct electricity.

3 According to the degree of saturation :

Solutions are divided into

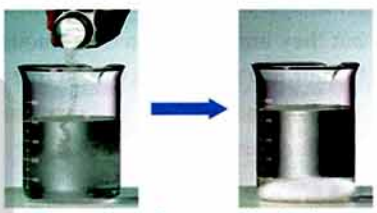
A Unsaturated solution | B Saturated solution | C Supersaturated solution

A. Unsaturated solution

It is the solution which contains less amount of solute and can accept more amount of solute at a certain temperature.

B. Saturated solution

It is the solution which contains the maximum amount of the solute at a certain temperature.



Formation of saturated solution

* The saturated solution can be obtained from the unsaturated solution by adding an excess amount of solute at a certain temperature.

C. Supersaturated solution

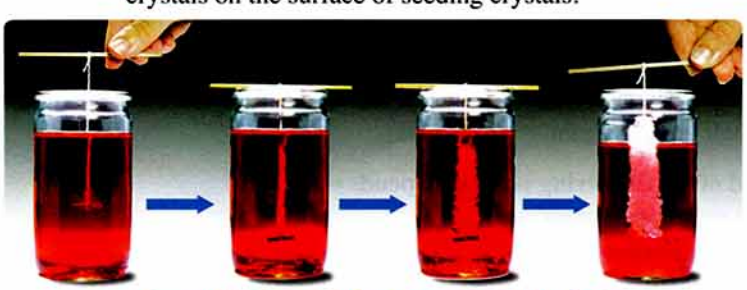
It is the solution that accepts more amount of solute substance after reaching the state of saturation.

* The supersaturated solution can be obtained by heating the saturated solution and adding more of the solute to it.

How can you prepare a saturated solution from a supersaturated solution by two methods ?

a. Cooling : cool the supersaturated solution and leave it for a short time, the excess solute will be separated (precipitate) from the solution.

b. Crystallization : put small crystals from the solute in the supersaturated solution and leave it for a short time, the solute molecules will be precipitated as crystals on the surface of seeding crystals.



Formation of crystals from supersaturated solution

UNIT 3

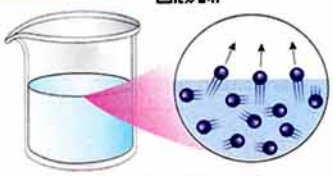
Dissolving process

Dissolving process

It is the process that occurs when the solute decomposes or dissociates into negative and positive ions or into separated polar molecules. Each of them binds to the molecules of the solvent.

The mechanism of dissolving process

Although water molecules seem static in the beaker, but they are really in a continuous motion, specially the surface molecules (due to their kinetic energy).



Water molecules are in a continuous motion

Dissolving ionic compounds and polar compounds in a polar solvent.

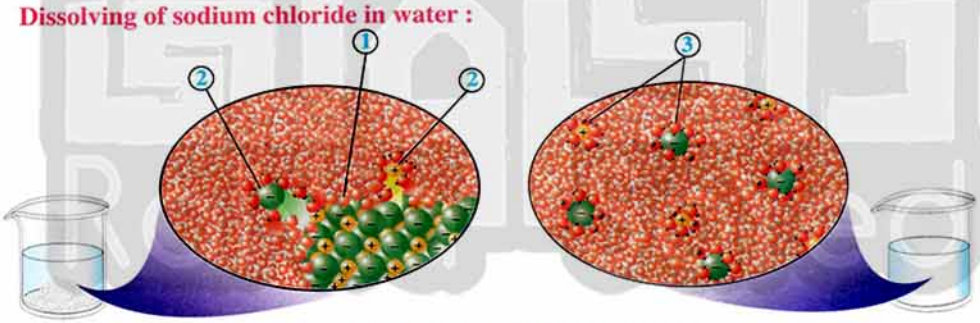
It's easy to dissolve :

- Ionic compound (as sodium chloride).
- Polar covalent compound (as hydrogen chloride gas).

} in polar solvents (as water)

Example

Dissolving of sodium chloride in water :



Dissolving process of NaCl in water

1. The polar water molecules collide with the crystals of NaCl by their kinetic energy.
2. Water molecules attract Na^+ and Cl^- ions by directing the suitable pole towards them to be separated from NaCl crystal.
3. Water molecules which surround the ions isolate positive ions from negative ions and prevent their binding again.

☆ **The speed of the dissolving process depends on :**

1. Surface area of the solute.
2. The stirring process.
3. Temperature.

Solubility

Solubility

- It is the ability of the solute to dissolve in a certain solvent.
- It is the ability of the solvent to dissolve a certain solute.

Degree of solubility

It is the amount of solute in grams, which dissolves in 100 g of solvent to form a saturated solution at standard temperature and pressure (STP).

Factors affecting the Solubility

1. The nature of solute and solvent.
2. The temperature.

1 The nature of solvent and solute

"Like dissolves like" is a well known statement which controls the solubility process, this statement can be explained as follows :

Polar solvent → **water** → Dissolves

- **Ionic compounds**: Sodium chloride NaCl; Sodium hydroxide NaOH; Nickel nitrate $Ni(NO_3)_2$
- **Polar compounds**: Hydrogen chloride HCl; Ammonia NH_3

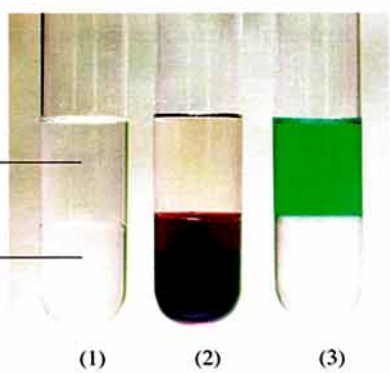
Non-polar solvent (organic solvent)

- **Benzene** → Dissolves → **Non-polar compounds**: Methane, oil, fats.
- **Methane dichloride** → Dissolves → **Non-polar material**: Iodine.

Application **Solubility of some substances in polar and non-polar solvents :**

The opposite figure shows three tubes, each one contains a heterogeneous mixture of water and methane dichloride :

- In the tube no.1 the methane dichloride doesn't dissolve in water. GR.



⇨ Because water is a polar solvent, while the methane dichloride is a non-polar substance. In which the non-polar substances don't dissolve in polar solvents.

- In the tube no.2 by adding the iodine solution to that heterogeneous mixture, it dissolves in methane dichloride, but doesn't dissolve in water. GR.

⇨ Because the iodine solution is a non-polar substance and methane dichloride also is a non-polar solvent, but water is a polar solvent. In which the non-polar substances don't dissolve in the polar solvents, but dissolve in the non-polar solvents.

- In the tube no.3 by adding green nickel nitrate to that heterogeneous mixture, it dissolves in water and doesn't dissolve in methane dichloride. GR.

⇨ Because nickel nitrate is a polar substance and water is a polar solvent, while methane dichloride is a non-polar solvent. In which the ionic substances dissolve in the polar solvents, but don't dissolve in the non-polar solvents.

Give reasons :

1 Oil is insoluble in water.

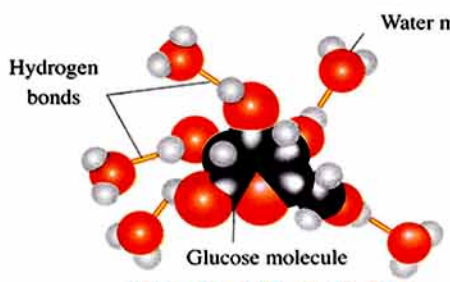
Because water is a polar solvent and oil is a non-polar compound. So, oil doesn't dissolve in water.

2 Oil is soluble in benzene.

Because oil (non-polar substance) is dispersed between molecules of benzene (non-polar solvent) due to the weak bonds between the benzene molecules.

3 Sugar is soluble in water, although sugar is a non-polar substance.

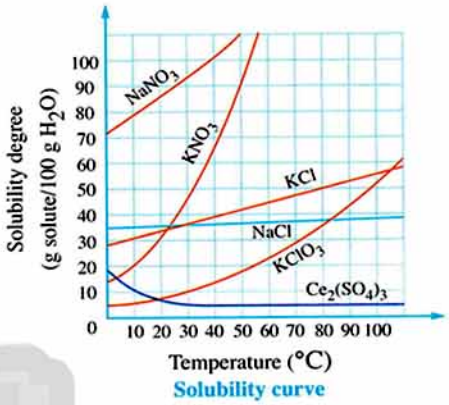
Because the water molecules make hydrogen bonds with the sugar molecules (polar hydroxyl groups) as shown in figure.



Dissolving of glucose in water

2 Effect of temperature on solubility

Observe the opposite diagram which shows the solubility of several salts as a function of temperature.



Solubility curve

There are three cases :

1 The solubility of most ionic substances increases greatly by increasing the temperature, such as $NaNO_3$, KNO_3 , KCl and $KClO_3$

i.e. The solubility degree of potassium nitrate (KNO_3) is 20 g/100 g $H_2O_{(l)}$ at 10°C. On raising the temperature to 50°C, the solubility increases and becomes 90 g/100 g $H_2O_{(l)}$

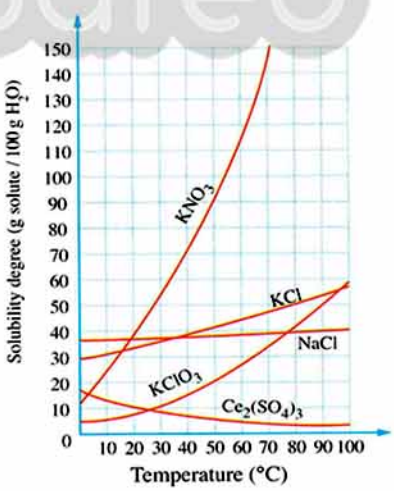
2 The solubility of some ionic substances increases slightly by increasing the temperature, such as NaCl

3 The solubility of some ionic substances decreases by increasing the temperature, such as $Ce_2(SO_4)_3$

Example

Study the diagram, then answer the following questions :

1. Which substance that its solubility increases with decreasing the temperature ?
2. What is the difference in mass of KNO_3 which is dissolved in a saturated solution of it, when heated from 40°C to 70°C ?
3. Calculate the required mass of KCl for dissolving in 200 g of water to form a saturated solution at 80°C.
4. Calculate the mass of the precipitated $KClO_3$ after cooling a saturated solution of it, from 50°C to 30°C.



UNIT 3

Solution

1. $Ce_2(SO_4)_3$, its solubility increases with decreasing temperature.
2. The difference in mass of potassium nitrate = 140 – 70 = 70 g
3. 50 g KCl ⟶ 100 g H_2O to form a saturated solution.

   X g KCl ⟶ 200 g H_2O to form a saturated solution.

   $\therefore X = \frac{50 \times 200}{100} = 100$ g to form a saturated solution.
4. Mass of the precipitated $KClO_3$ = 20 – 10 = 10 g

Properties of solution :

- The particles of solution can't be distinguished by the naked eye or by the electron microscope.
- The diameter of its particles (ions or molecules) is less than 1 nm.
- The particles forming the solution are regularly distributed. So, the solution is homogeneous in its composition and properties.
- The particles don't scatter the beam of light passing through the solution.

The solution doesn't scatter the light falling on it.

Concentration of solutions

The ratio of the amount of the solute to that of the solvent affects the concentration of solution to be diluted or concentrated.

Concentrated solution

The solution in which the amount of the solute is large (not larger than the solvent).

Diluted solution

The solution in which the amount of the solute is small in proportion to the amount of the solvent.

- In this section we will describe several methods for expressing the concentration which are :

1 Percentage 2 Molarity 3 Molality

1 Percentage

This method is suitable to express concentration for food and medicines.

A Mass percentage (m/m)

Mass percentage

It is the percentage of the mass of solute in 100 g of solution.

$$\text{Mass percentage} = \frac{\text{Solute mass (g)}}{\text{Solution mass (g)}} \times 100\%$$

Solution mass = Solute mass + Solvent mass

Preparation of an aqueous solution of sucrose 10% (m/m).

$$\therefore \text{Mass percentage} = \frac{10\text{ g}}{100\text{ g}} \times 100\% = 10\%$$

B Volume percentage (v/v)

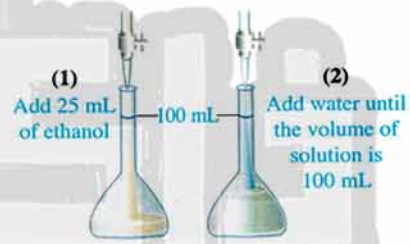
Volume percentage

It is the percentage of the volume of solute in 100 mL of solution.

$$\text{Volume percentage} = \frac{\text{Solute volume (mL)}}{\text{Solution volume (mL)}} \times 100\%$$

Solution volume = Solute volume + Solvent volume

Preparation of an equeous solution of ethanol 25% (v/v).



$$\therefore \text{Volume percentage} = \frac{25\text{ mL}}{100\text{ mL}} \times 100\% = 25\%$$

Give reason :

Some solutions are prepared on a volume percentage.

Because liquid volumes are so easily to be measured.

What is meant by ... ?

(1) The mass percentage of a solution is 25%

It means that the mass of the solute in 100 g of the solution equals 25 g.

(2) The volume percentage of a solution is 20%

It means that the volume of the solute in 100 mL of the solution equals 20 mL.

Note

The stickers placed on medicines and nutritional substances must show the units that express the solute percentage, due to the presence of many types of percentage.

UNIT 3

Examples

1 An ethanol-water solution is prepared by dissolving 10 mL of ethanol (d = 0.789 g/mL) in a sufficient volume of water to produce 100 mL of solution with a density of 0.982 g/mL. What is the concentration of ethanol in this solution expressed as :

(a) Volume percentage. (b) Mass percentage.

Solution

(a) Volume percentage of ethanol $= \frac{\text{ethanol volume}}{\text{solution volume}} \times 100\%$

$= \frac{10\ \text{mL}}{100\ \text{mL}} \times 100\% = 10\%$

(b) Mass percentage (m/m)

Mass of ethanol = volume of ethanol × its density

$= 10\ \text{mL} \times 0.789\ \frac{\text{g}}{\text{mL}} = 7.89\ \text{g}$

Mass of solution = volume of solution × its density

$= 100\ \text{mL} \times 0.982\ \frac{\text{g}}{\text{mL}} = 98.2\ \text{g}$

Mass percentage of ethanol $= \frac{\text{ethanol mass}}{\text{solution mass}} \times 100\%$

$= \frac{7.89}{98.2} \times 100\% = 8.03\%$

2 Calculate the mass percentage of the solution of 15 g of KCl in 100 g of water.

Solution

$(\text{m/m})\% = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\% = \frac{15\ \text{g}}{115\ \text{g}} \times 100\% = 13.04\%$

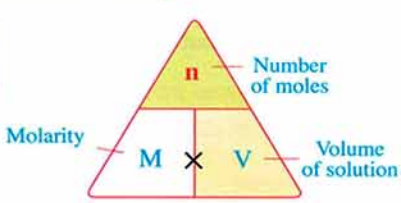
2 Molarity (M)

Molarity

It is the number of moles of solute dissolved in one litre of solution.

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute (mol)}}{\text{Volume of solution (L)}}$$

$$\text{n} = \frac{\text{Mass of solute (g)}}{\text{Molar mass (g/mol)}}$$



The unit of molarity is (mol/L) or Molar (M).

Examples

❶ Calculate the molarity for 85.5 g cane-sugar $C_{12}H_{22}O_{11}$ in a certain amount of water to form 0.5 L of solution. [C = 12 , H = 1 , O = 16]

Solution

Molar mass of the cane-sugar = (12 × 12) + (22 × 1) + (11 × 16) = 342 g/mol

$$\text{Number of moles of sugar} = \frac{\text{mass}}{\text{molar mass}} = \frac{85.5\text{ g}}{342\text{ g/mol}} = 0.25\text{ mol}$$

$$\text{Molarity} = \frac{\text{number of moles of solute (mol)}}{\text{volume of solution (L)}} = \frac{0.25\text{ mol}}{0.5\text{ L}} = 0.5\text{ mol/L}$$

❷ Write steps of preparing an aqueous solution of sodium carbonate Na_2CO_3, its volume 200 mL and its concentration is 0.2 M. [Na = 23 , C = 12 , O = 16]

Solution

(1) Put 4.24 g of Na_2CO_3 in a flask.

(2) Add 50 mL water to the flask.

(3) Complete the solution by adding water till 200 mL.

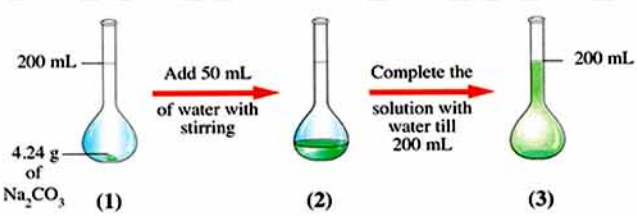
To calculate mass of 0.2 M of Na_2CO_3

Molar mass of Na_2CO_3 =

$2 \times 23 + 12 + 16 \times 3 = 106$ g/mol

$$\text{No. of moles} = 0.2 \times \frac{200}{1000} = 0.04\text{ mol}$$

Mass = 0.04 × 106 = 4.24 g



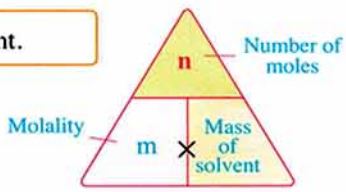
UNIT 3

3 Molality (m)

Molality

It is the number of moles of solute in one kilogram of solvent.

$$\text{Molality (m)} = \frac{\text{Number of solute moles (mol)}}{\text{Mass of solvent (kg)}}$$



The unit of molality is mol/kg or (m).

Examples

1 Calculate the molality of a solution prepared by dissolving 20 g of sodium hydroxide NaOH in 800 g of water. [Na = 23 , H = 1 , O = 16]

Solution

Molar mass of NaOH = 23 + 16 + 1 = 40 g/mol

$$\text{Number of moles of NaOH} = \frac{\text{mass}}{\text{molar mass}} = \frac{20}{40} = 0.5 \text{ mol}$$

$$\text{Molality} = \frac{\text{number of moles of solute (mol)}}{\text{mass of solvent (kg)}} = \frac{0.5 \text{ mol}}{0.8 \text{ kg}} = 0.625 \text{ mol/kg}$$

2 Calculate the concentration of a solution produced from mixing 1 g of ethanol C_2H_5OH with 99 g of water H_2O, expressed by :

(a) The mass percentage.

(b) Molality. [C_2H_5OH = 46 g/mol]

Solution

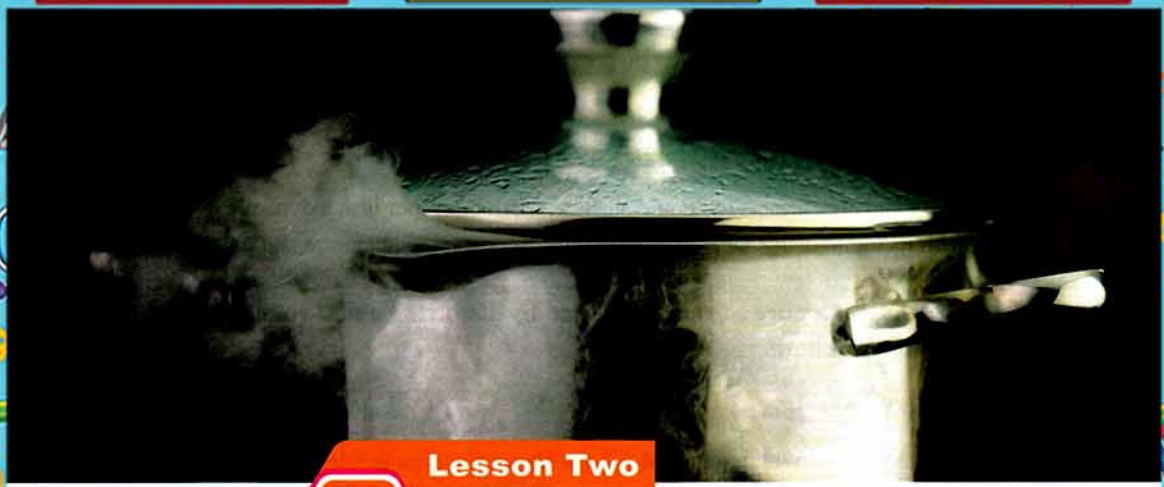
(a) Mass of solution = 1 + 99 = 100 g

$\therefore$ The mass percentage = $\frac{1}{100} \times 100\% = 1\%$

(b) No. of ethanol moles = $\frac{1}{46} = 0.0217$ mol

$\therefore$ Mass of solvent = $\frac{99}{1000} = 0.099$ kg

$\therefore$ Molality = $\frac{0.0217}{0.099} = 0.219$ m



Lesson Two

Chapter 1 Collective Properties of Solutions, Suspensions and Colloids

- The properties of solutions differ from the properties of the pure solvents forming them after dissolving a non-volatile substances at the same conditions, these new properties are called Colligative properties.

Colligative (Collective) properties of solutions

They are properties whose values depend only on the number of solute particles per unit volume of solution and not on the type of solute.

Collective properties of solutions are :

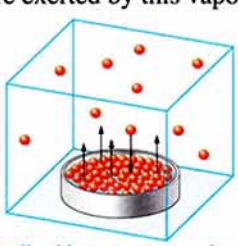
1 Vapor pressure depression 2 Boiling point elevation 3 Freezing point depression

1 Vapor pressure depression

- When a pure liquid is left in an open beaker, it evaporates completely.
- But, when it is left in a closed container, both liquid and vapor are present.

i.e. Vaporization and condensation occur.

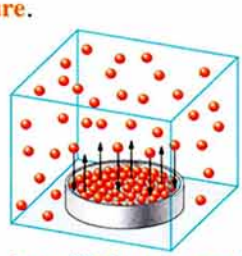
- At equilibrium, the rate of condensation is equal to the rate of vaporization and the pressure exerted by this vapor is called Vapor pressure.



The liquid starts to vaporize, the rate of vaporization is higher than the rate of condensation.

after

a period of time



At equilibrium, the rate of condensation equals to the rate of vaporization.

UNIT 3

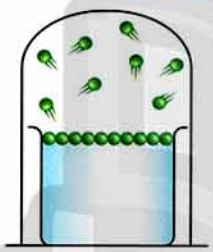
Vapor pressure

It is the pressure that vapor affects the liquid surface, when the vapor is at a dynamic equilibrium with its liquid inside a closed container at a constant temperature and pressure.

The vapor pressure of a pure solvent is affected by dissolving a non-volatile solute in it to form a solution as follows :

Pure solvent

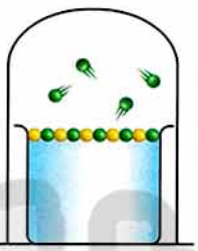
- The surface molecules which exposed to vaporization process are the solvent molecules only.
- The force that has to be overcome is the attraction force between the solvent molecules with each other.



Pure solvent

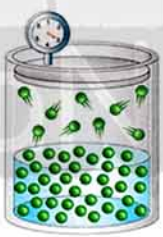
Solution

- The surface molecules are the solvent and the solute molecules.
- The number of solvent molecules which exposed to vaporization process decreases.
- The force that has to be overcome is the attraction force between solvent and solute molecules.



Solution

So, the vapor pressure of a pure solvent is higher than the vapor pressure of the solution at the same temperature.



Vapor pressure of a pure solvent

Vapor pressure of a solution

Explain why the vapor pressure of the solution is lower than the vapor pressure of the pure solvent ?

Because :

- The number of solvent surface molecules in solution is less than that in the pure solvent.
- The attraction force between solvent and solute molecules in the solution is stronger than the attraction force between solvent molecules with each other.

So, the number of solvent molecules which exposed to vaporization process decreases in the solution.

2 Boiling point elevation

When the vapor pressure of the liquid equals the atmospheric pressure, the liquid starts to boil and in this case the boiling point of the liquid is called The natural (normal) boiling point.

The natural (normal) boiling point

It is the temperature at which the vapor pressure of the liquid equals the atmospheric pressure.

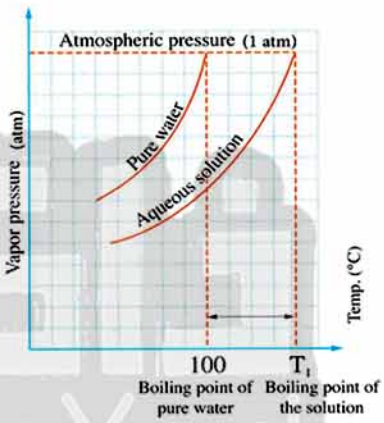
- The boiling point can be used as an indicator for the purity of solvent. GR.

  ⇨ Because the measured boiling point of the pure liquids equals its natural boiling point.

Application

Observe the opposite graph :

- Pure water is boiled at 100°C at atmospheric pressure (1 atm). However, the addition of a certain quantity of salt in water raises the boiling point of the solution to T_1



The relation between the vapor pressure of water and the change in the boiling point of solution.

Explain why the boiling point of solution is higher than the boiling point of pure solvent which forms it.

Because the vapor pressure of solution is lower than the vapor pressure of pure solvent which forms it.

So, the solution needs more energy until its vapor pressure equals to atmospheric pressure to boil.

Measured boiling point

It is the temperature at which the vapor pressure of the liquid equals the pressure exerted or acted on it.

Note

Boiling point elevation is directly proportional to the number of moles of ions in the solution.

Give reasons :

1. The boiling point of an aqueous solution of sodium chloride is equal to the boiling point of an aqueous solution of potassium nitrate.

UNIT 3

$NaCl_{(s)} \xrightarrow{H_2O_{(l)}} Na^+_{(aq)} + Cl^-_{(aq)}$ | $KNO_{3(s)} \xrightarrow{H_2O_{(l)}} K^+_{(aq)} + NO^-_{3(aq)}$

1 mol — 2 mol | 1 mol — 2 mol

Because each of them produces the same number of moles of ions in the solution.

❷ The boiling point of an aqueous solution of sodium carbonate Na_2CO_3 is higher than the boiling point of an aqueous solution of the sodium chloride NaCl which has the same concentration.

$Na_2CO_{3(s)} \xrightarrow{H_2O_{(l)}} 2Na^+_{(aq)} + CO^{2-}_{3(aq)}$ | $NaCl_{(s)} \xrightarrow{H_2O_{(l)}} Na^+_{(aq)} + Cl^-_{(aq)}$

1 mol — 3 mol | 1 mol — 2 mol

Because the number of moles of ions dissolved in the solution of Na_2CO_3 is higher than that in the solution of NaCl and the boiling point increases by increasing the number of moles of ions dissolved in the solution.

3 Freezing point depression

- Freezing point of solution is less than freezing point of pure solvent which forms it.
- Freezing point depression is **directly proportional** to the number of dissolved solute particles in solution.

Dissolved solute particles

Solute molecules

- When the substance is not ionized into ions in water **e.g. sugar** (non-electrolyte).
- When 1 mol of any non-electrolyte is dissolved in 1 kg of water the resulting solution freezes at (– 1.86°C).

Example

- Solution of 1 mol (180 g) of glucose in 1 kg of water freezes at (– 1.86°C).

Glucose solution

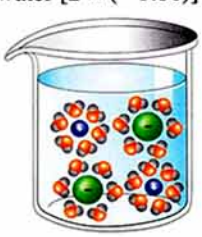
Solute ions

- When the substance is dissociated into ions in water **e.g. NaCl** (electrolyte).

The freezing point of electrolytic solution = number of moles of ions in the solution × (– 1.86°C).

Example

- Solution of 1 mol (58.5 g) of NaCl in 1 kg of water freezes at (– 3.72°C). Because 1 mol of NaCl produces 2 mol of ions in water [2 × (– 1.86)]= – 3.72°C



NaCl solution

Give reasons :

1 The freezing point of a solution is less than the freezing point of its pure solvent.

Because the attraction forces between solvent and solute molecules prevent the transformation of solvent molecules from liquid state to solid state at the freezing point of pure solvent.

So, the temperature of solution has to drop below the freezing point of pure solvent until solvent particles are separated from the solute crystals.

2 Adding salt to snow-covered roads in cold places.

To prevent cars from slipping and decrease the number of accidents where the salt dissolves in water forming a solution, which freezes at a temperature below the freezing point of pure water.

So, the amount of snow will decrease.

Adding salt to snow-covered roads

Examples

1 What is the freezing point of the solution, that conains 1 mol of calcium chloride $CaCl_2$ in 1000 g of water ?

Solution

$$CaCl_{2(s)} \xrightarrow{H_2O_{(l)}} Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

1 mol → 3 mol

The freezing point of an electrolytic solution = no. of moles of ions × (– 1.86°C)

= 3 × (– 1.86°C) = – 5.58°C

2 What is the relation between the properties of solution and the properties of the solvent forming it, according to : the vapor pressure, the boiling point and the freezing point ?

Solution

The vapor pressure	of	the solution	<	that of the solvent.
The boiling point	of	the solution	>	that of the solvent.
The freezing point	of	the solution	<	that of the solvent.

UNIT 3

Suspensions

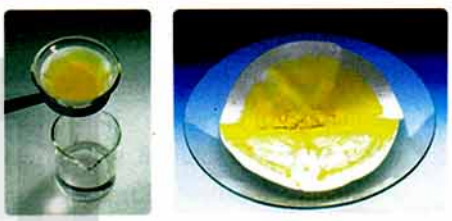
Properties of suspensions :

1. A heterogeneous mixture.
2. The diameter of its particles is larger than 1000 nm.
3. The suspended particles precipitate, if it is left for a short time without shaking.
4. The suspended particles can be seen by the naked eye.
5. The suspended particles can be separated by filtration. GR.

⇒ Because filter paper (ultra filtration membrane) can hold the suspended particles, while water passes through it.

Suspension

It is a heterogeneous mixture in which the diameter of its particles is larger than 1000 nm and can be distinguished by the naked eye.



Filtration of suspension

Examples

- Sand in water.
- Chalk's powder in water.

Colloids

Properties of colloids :

1. A heterogeneous mixture (apparently homogeneous).
2. The diameter of the dispersed particles is 1 – 1000 nm.
3. The dispersed particles don't precipitate, if they are left for a short time without shaking.
4. The dispersed particles can be seen by the electron microscope only.
5. The dispersed particles can't be separated by filtration.
6. The shape depends on its concentration :
   - Concentrated colloids appear as milk or clouds.
   - Diluted colloids appear clear.

Colloid

It is a heterogeneous mixture in which the diameter of its dispersed particles ranges between 1 : 1000 nm and can be distinguished by the electron microscope.

Aerosols are from colloids which take clouds shape

Give reason :

The colloid is an intermediate case between the solution and the suspension.

Because the diameter of colloid particles is in the range 1 : 1000 nm, which is smaller than that of suspension (> 1000 nm) and larger than that of solution (< 1 nm).

Tendal's phenomenon

To distinguish between the colloid and the true solution, this is known as Tendal's phenomenon. By allowing a beam of light from a lamp to fall on each one, the colloid scatters the light because the size of the colloid particles is larger enough.

Solution allows a beam of light to pass but colloid scatters it.
" Tendal's phenomenon"

Colloidal systems

Colloidal systems consist of :

- **Dispersed phase** (like the **solute** in the solution).
  It is the substance that forms the colloidal particles.
- **Dispersed medium** (like the **solvent** in the solution).
  It is the medium in which the colloidal particles are dispersed.

Classification of colloidal systems according to the state :

Dispersed phase	Dispersed medium	Examples
Gas	Liquid	Some types of creams – whipped egg.
	Solid	Sweet made of sugar and egg white.
Liquid	Gas	Aerosols – fog.
	Liquid	Milk – mayonnaise – emulsion of oil and vinegar.
	Solid	Hair gel.
Solid	Gas	Dust in air particles.
	Liquid	Pigment – blood – starch in hot water.

Pigment

Blood

Give reason :

There is no gas-gas colloidal system.

Because mixed gases are homogeneous mixtures, whereas the colloid is a heterogeneous mixture.

UNIT 3

What happens when an amount of egg white is whipped by an electric mixture ?
A colloidal system (gas in liquid type) is formed.

Preparation methods of Colloids

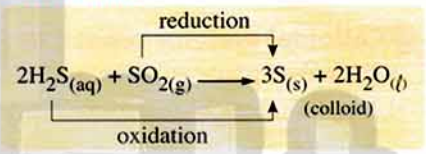
There are two methods :

1 Dispersion method :
The substance is crushed into small particles until its diameter reaches between (1 : 1000 nm), then added to the dispersed medium with stirring.
e.g. : starch in hot water and cappuccino coffee.


Cappuccino foam is formed by dispersion method through fast stirring

2 Condensation method :
The small particles are collected together into larger particles have the volume of the colloid particles, by some processes like :
- **Hydrolysis.**
- **Oxidation – reduction.**

e.g. : such as in the reaction of hydrogen sulphide with sulphur dioxide, where the atoms of sulphur in water form colloid.



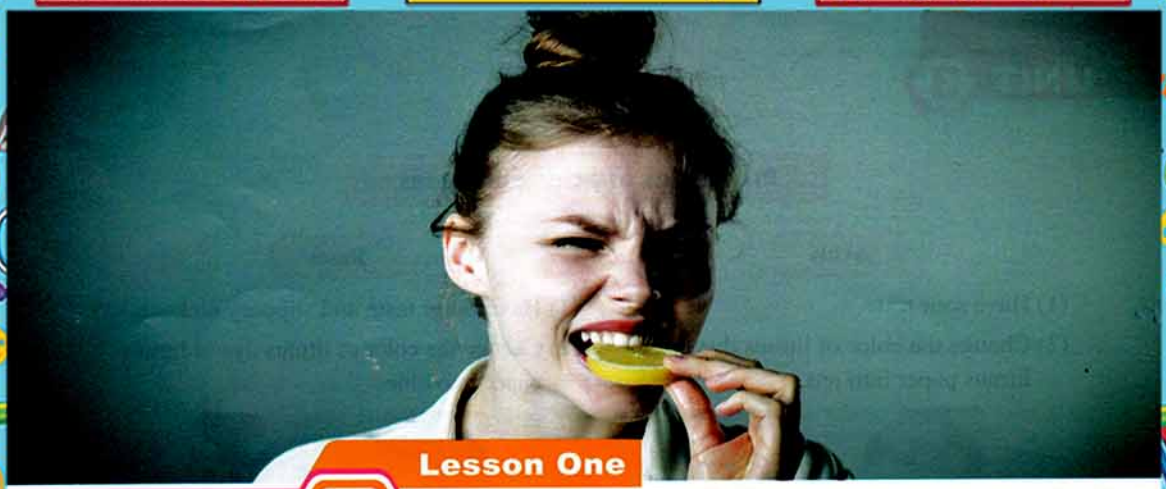
Comparison between solution, colloid and suspension :

Points of comparison	Solution	Colloid	Suspension
1. Homogeneity :	Homogeneous.	Heterogeneous.	Heterogeneous.
2. Size of particles :	< 1 nm.	1 : 1000 nm.	> 1000 nm.
3. Vision :	Can't be seen by the naked eye or the electron microscope.	Can't be seen by the naked eye, but seeing by the electron microscope.	Can be seen by the naked eye.
4. Scattering of light beam :	Doesn't scatter the light.	Scatters the light.	Scatters the light.
5. Precipitation :	No precipitate.	No precipitate.	Precipitate.
6. Filtration (separation) of particles :	Can't be separated.	Can't be separated.	Can be separated.

Give reasons :

1 Sugar dissolves in water forming a solution, but milk powder disperses in water forming a colloid.
Because the size particles of sugar after dissolving is < 1 nm, but that in case of milk powder ranges between 1 : 1000 nm.

2 Chalk's powder forms a suspension in water.
Because the size of chalk's particles is > 1000 nm.



Lesson One

Chapter 2 Properties of Acids and Bases

The acids and bases represent a large part of human life. For example, the vinegar that is used in some food and cleaning processes is an acidic solution that was early discovered.

Acids are used in many chemical industries like :

- Fertilizers.
- Medicines.
- Plastic.
- Car batteries.

Bases also have many uses in chemical industries like :

- Soap.
- Detergents.
- Dyes.
- Medicines.

Medicines are acids and bases

Detergents are bases

Lemon and tomato contain acids

☆ **The following tables show some of the natural and industrial products and the acids and bases entering in their composition or preparation :**

Product	Acids entering in its composition or preparation
Acidic plants (lemon - oranges - tomatoes)	Citric acid – Ascorbic acid.
Dairy products (milk - cheese - yoghurt)	Lactic acid.
Soft drinks	Carbonic acid – Phosphoric acid.

Product	Bases entering in its composition or preparation
Soap	Sodium hydroxide.
Baking soda	Sodium bicarbonate.
Washing soda	Hydrated sodium carbonate.

UNIT 3

Properties of acids and bases

Acids

(1) Have sour taste.

(2) Change the color of litmus dye or litmus paper into red.

Acids change the color of litmus dye into red.

(3) Acids react with bases producing salt and water.

$NaOH_{(aq)}$ + $HNO_{3(\ell)}$ → $NaNO_{3(aq)}$ + $H_2O_{(\ell)}$

Sodium hydroxide (base) + Nitric acid (acid) → Sodium nitrate (salt) + water

Bases

(1) Have bitter taste and slippery feel.

(2) Change the color of litmus dye or litmus paper into blue.

Bases change the color of litmus dye into blue.

(3) Bases react with acids producing salt and water.

Acids react with :

- **Active metals :**

Producing salt of acid and hydrogen gas H_2 evolves.

$Zn_{(s)}$ + $2HCl_{(aq)}$ → $ZnCl_{2(aq)}$ + $H_{2(g)}\uparrow$

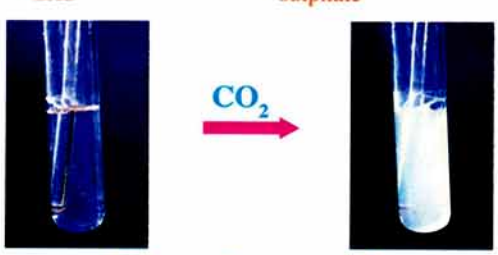
Zinc + Hydrochloric acid → Zinc chloride + Hydrogen gas

- **Carbonate or bicarbonate salts :**

Causing effervescence and producing carbon dioxide gas CO_2 which makes limewater turbid.

$Na_2CO_{3(s)}$ + $H_2SO_{4(aq)}$ → $Na_2SO_{4(aq)}$ + $H_2O_{(\ell)}$ + $CO_{2(g)}\uparrow$

Sodium carbonate + Sulphuric acid → Sodium sulphate + Water + Carbon dioxide gas



CO_2 turns limewater turbid.

Theories defining acids and bases

- The external appearance of the acid and base leads to an experimental definition for each.
- The experimental definition is based on observation only and doesn't describe or explain the unseen properties.
- The more overall definitions of acid and base come from the studies and experiments, that were placed in the form of theories.

Acid-base theories

1. Arrhenius's theory
2. Brönsted-Lowry's theory
3. Lewis's theory

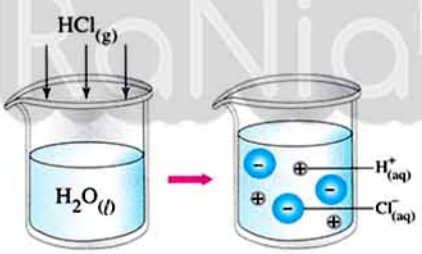
1 The Arrhenius's theory in 1887

- Arrhenius observed that the aqueous solutions of acids and bases conduct electricity.
- This observation proves that acids and bases are ionized in water.

Dissolving of hydrogen chloride in water

- When hydrogen chloride gas dissolves in water, it is ionized into hydrogen ions (H^+) and chloride ions (Cl^-).

$$HCl_{(g)} \xrightarrow{H_2O_{(l)}} H^+_{(aq)} + Cl^-_{(aq)}$$

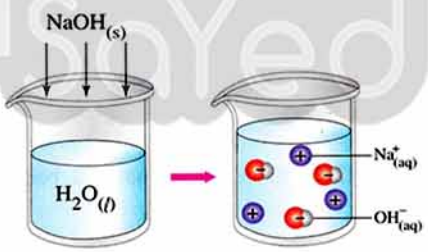


$HCl_{(g)}$ in water

Dissolving of sodium hydroxide in water

- When sodium hydroxide dissolves in water, it is dissociated to sodium ions (Na^+) and hydroxide ions (OH^-).

$$NaOH_{(s)} \xrightarrow{H_2O_{(l)}} Na^+_{(aq)} + OH^-_{(aq)}$$



$NaOH_{(s)}$ in water

Observe that

Dissolving of acid in water produces hydrogen ions.

$$H_2SO_{4(aq)} \xrightarrow{H_2O_{(l)}} H^+_{(aq)} + HSO^-_{4(aq)}$$

$$HClO_{4(aq)} \xrightarrow{H_2O_{(l)}} H^+_{(aq)} + ClO^-_{4(aq)}$$

Dissolving of base in water produces hydroxide ions.

$$KOH_{(aq)} \xrightarrow{H_2O_{(l)}} K^+_{(aq)} + OH^-_{(aq)}$$

$$Ba(OH)_{2(aq)} \xrightarrow{H_2O_{(l)}} Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$$

UNIT 3

Arrhenius revealed (proved) his theory to define acids and bases

Arrhenius acid

It is the substance that dissolves in water and ionized or dissociated giving one or more hydrogen ions (H^+).

Arrhenius base

It is the substance that dissolves in water and ionized or dissociated giving one or more hydroxide ions (OH^-).

According to Arrhenius's theory we observe that

Arrhenius acid must contain a source of hydrogen ions (H^+).

Arrhenius base must contain a source of hydroxide ions (OH^-).

So,

Acid works on increasing the concentration of (H^+) ions in the aqueous solutions.

Base works on increasing the concentration of (OH^-) ions in the aqueous solutions.

Example

Classify the following substances into Arrhenius acid or Arrhenius base :

❶ $HNO_{3(\ell)}$ ❷ $Mg(OH)_{2(s)}$

Solution

❶ $HNO_{3(\ell)} \xrightarrow{H_2O_{(\ell)}} H^+_{(aq)} + NO^-_{3(aq)}$

∴ HNO_3 is an Arrhenius acid, because it dissolves in water giving H^+ ions.

❷ $Mg(OH)_{2(s)} \xrightarrow{H_2O_{(\ell)}} Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$

∴ $Mg(OH)_2$ is an Arrhenius base, because it dissolves in water giving OH^- ions.

Explaining neutralization reaction according to Arrhenius's theory

Neutralization reaction

It is the reaction between an acid and a base to produce salt and water.

Application

$HCl_{(aq)}$ + $NaOH_{(aq)}$ ⟶ $NaCl_{(aq)}$ + $H_2O_{(l)}$

Hydrochloric acid — Sodium hydroxide — Sodium chloride — Water

- The ionic equation of this reaction according to Arrhenius's theory is :

$$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

$Na^+_{(aq)}$ and $Cl^-_{(aq)}$ ions are present in both sides of the equation without changing. So, they can be neglected (cancelled) from the both sides of the chemical equation. So, the neutralization reaction can be represented by the following equation :

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$$

Observations on (Deffects of) Arrhenius's theory

- Carbon dioxide CO_2 doesn't contain a source of (H^+) ions, but it dissolves in water giving an aqueous acidic solution.
- Ammonia NH_3 doesn't contain a source of (OH^-) ions, but it dissolves in water giving an aqueous basic solution.
- These observations don't agree with Arrhenius's theory.

2 The Brönsted-Lowry's theory in 1923

The Danish scientist Brönsted and the British one Lowry proposed a new acid-base theory.

Brönsted-Lowry acid

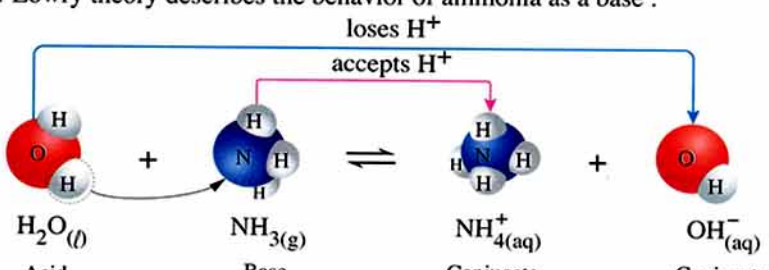
It is the substance that gives up the proton (H^+).
Proton donor

Brönsted-Lowry base

It is the substance that accepts the proton (H^+).
Proton acceptor

Application

Brönsted-Lowry theory describes the behavior of ammonia as a base :



Acid and base definition according to Brönsted-Lowry's theory

UNIT 3

When ammonia gas dissolves in water

- H_2O acts as an acid. GR
  ⇒ Because it gives up a proton (H^+) to ammonia molecule (NH_3).
- NH_3 acts as a base. GR
  ⇒ Because it accepts the proton (H^+) from water molecule.

As a result of this transfer

- OH^- formed and it is called Conjugate base.
- NH_4^+ formed and it is called Conjugate acid.

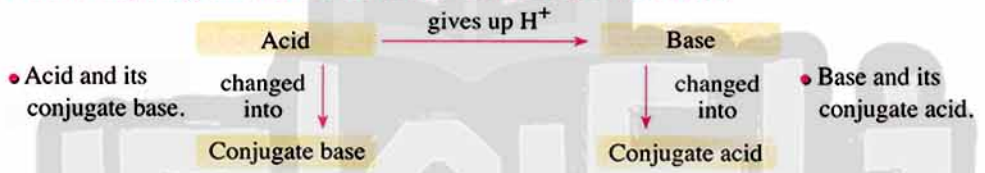
Conjugate base

It is the substance which is formed when the acid loses a proton (H^+).

Conjugate acid

It is the substance which is formed when the base accepts a proton (H^+).

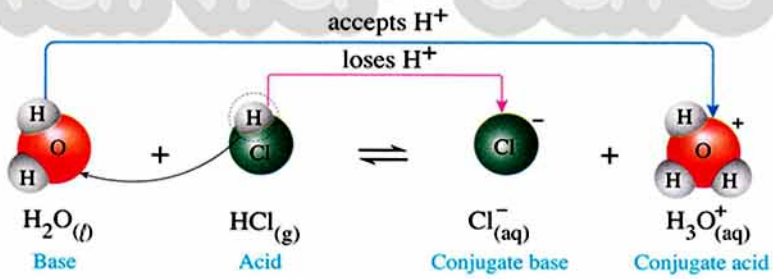
The following diagram shows the relation between acid and base :



Examples

1 Show by a chemical equation the dissolving of hydrogen chloride gas $HCl_{(g)}$ in water according to Brönsted-Lowry's theory, then identify acid, base and their conjugates.

Solution



* **The acid** is hydrogen chloride gas $HCl_{(g)}$
* **The base** is water H_2O
* **The conjugate base** is chloride ion $Cl^-_{(aq)}$
* **The conjugate acid** is hydronium ion $H_3O^+_{(aq)}$

2 Explain the following chemical reactions in the light of Brönsted-Lowry's theory :

(a) $CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$

(b) $HCO^-_{3(aq)} + H_2O_{(\ell)} \rightleftharpoons H_2CO_{3(aq)} + OH^-_{(aq)}$

(c) $HCO^-_{3(aq)} + H_2O_{(\ell)} \rightleftharpoons CO^{2-}_{3(aq)} + H_3O^+_{(aq)}$

Solution

Reaction	Acid	Base	Conjugate base	Conjugate acid
(a)	$CH_3COOH_{(aq)}$	$H_2O_{(\ell)}$	$CH_3COO^-_{(aq)}$	$H_3O^+_{(aq)}$
(b)	$H_2O_{(\ell)}$	$HCO^-_{3(aq)}$	$OH^-_{(aq)}$	$H_2CO_{3(aq)}$
(c)	$HCO^-_{3(aq)}$	$H_2O_{(\ell)}$	$CO^{2-}_{3(aq)}$	$H_3O^+_{(aq)}$

3 Lewis's theory in 1923

Lewis proposed an acid-base theory which depends on sharing of a lone pair of electrons between acid and base.

Lewis acid

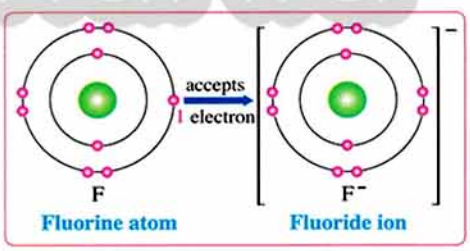
It is the substance that accepts an electron pair or more.

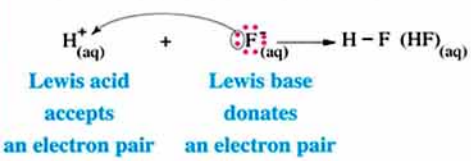
Lewis base

It is the substance that donates an electron pair or more.

Examples

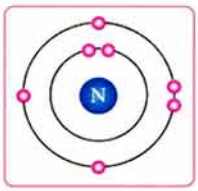
1 Lewis-theory explains the reaction of formation of hydrogen fluoride HF

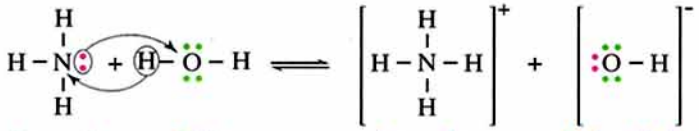




UNIT 3

2 Mention the acid and base according to Lewis's theory, when ammonia gas dissolves in water.





Ammonia Lewis base donates a lone pair of electrons

Water Lewis acid accepts a lone pair of electrons

Ammonium ion

Hydroxide ion

Give reason :

Ammonia is considered as a base, although it doesn't contain hydroxide group in its structure.

Because according to Brönsted-Lowry's theory, ammonia accepts a proton from another substance (as water) during the reaction and according to Lewis's theory it donates a lone pair of electrons to another substance (as water) during the reaction.

All the previous theories can be summarized as the following :

Theory	Acid definition	Base definition
Arrhenius	H^+ producer	OH^- producer
Brönsted-Lowry	H^+ donor	H^+ acceptor
Lewis	Electron pair acceptor	Electron pair donor

Lesson Two

Chapter 2 Classification of Acids and Bases

Acids can be classified according to :

1. Its strength (degree of ionization).
2. Its source.
3. Basicity.

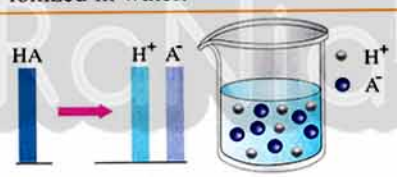
1 Classification of acids according to its strength (degree of ionization)

Acids are classified according to its degree of ionization in the aqueous solution into :

Strong acids

Strong acids

The acids which are completely ionized in water.



Strong acid

- Their aqueous solution conducts the electric current to a large degree.
- They are considered as strong electrolytes.

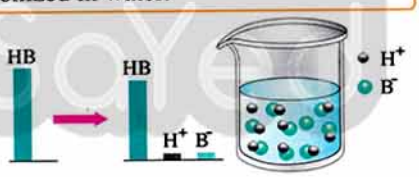
Examples

- Hydroiodic acid HI
- Hydrochloric acid HCl
- Hydrobromic acid HBr
- Sulphuric acid H_2SO_4
- Nitric acid HNO_3
- Perchloric acid $HClO_4$

Weak acids

Weak acids

The acids which are incompletely ionized in water.



Weak acid

- Their aqueous solution conducts the electric current to a small degree.
- They are considered as weak electrolytes.

Examples

- Carbonic acid H_2CO_3
- Phosphoric acid H_3PO_4
- Acetic acid (vinegar) CH_3COOH
- Formic acid.
- Citric acid.
- Oxalic acid.
- Lactic acid.

UNIT 3

Note

- There is no relation between the strength of the acid and the number of hydrogen atoms in its molecular structure.

  e.g. Phosphoric acid (H_3PO_4) is weaker than nitric acid (HNO_3), although it contains greater number of hydrogen atoms.

Questions :

- **Write the chemical equation that expresses the ionization of acetic acid in water.**

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

- **Give reason : Hydrochloric acid HCl is stronger than acetic acid.**

Because HCl is completely ionized in water, but acetic acid is partially ionized in water.

$$HCl_{(aq)} + H_2O_{(l)} \longrightarrow Cl^-_{(aq)} + H_3O^+_{(aq)}$$

2 Classification of acids according to their sources

Acids are classified according to their sources (origin) into :

Organic acids

- Acids that have an organic origin (plant or animal).

  i.e. They are extracted from the organs of living organisms.
- All of them are weak acids.

Examples

- Lactic acid (milk products).
- Acetic acid (vinegar).
- Citric acid (from lemon).
- Oxalic acid.
- Formic acid.

Mineral acids

- Acids that have no organic origin.

  i.e. They usually have non-metallic elements in their structure like chlorine, sulphur, nitrogen and phosphorus.
- Some of them are strong acids and others are weak.

Examples

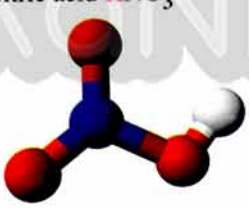
- Carbonic acid.
- Hydrochloric acid.
- Phosphoric acid.
- Perchloric acid.
- Nitric acid.
- Sulphuric acid.

3 Classification of acids according to the basicity

The basicity of acid

It is the number of hydrogen ions (H^+), which is produced by one molecule of the acid when it dissolves in water.

Acids are classified according to the basicity into :

Monobasic acids (Monoprotic)	Dibasic acids (Diprotic)	Tribasic acids (Triprotic)
Monobasic acids Acids where each molecule gives one proton H^+, when it dissolves in water.	**Dibasic acids** Acids where each molecule gives one or two protons H^+, when it dissolves in water.	**Tribasic acids** Acids where each molecule gives one, two or three protons H^+, when it dissolves in water.
Examples	**Examples**	**Examples**
• Organic monobasic acids : Formic acid $HCOOH$ Acetic acid CH_3COOH	• Organic dibasic acids : Oxalic acid $\begin{matrix}COOH\\|\\COOH\end{matrix}$	• Organic tribasic acids : Citric acid $\begin{matrix}H_2C-COOH\\\|\\HO-C-COOH\\\|\\H_2C-COOH\end{matrix}$
• Mineral monobasic acids : Hydrochloric acid HCl Nitric acid HNO_3	• Mineral dibasic acids : Sulphuric acid H_2SO_4 Carbonic acid H_2CO_3	• Mineral tribasic acids : Phosphoric acid H_3PO_4
 HNO_3 Monobasic	 H_2SO_4 Dibasic	 H_3PO_4 Tribasic

Give reason:

• **Both of citric acid and phosphoric acid have the same degree of basicity, while they differ in their source (origin).**

Because both of them are tribasic acids, but citric acid is an organic acid, while phosphoric acid is a mineral acid.

UNIT 3

Classification of bases

Bases can be classified according to :

1. **Strength (degree of ionization).**
2. **Molecular structure.**

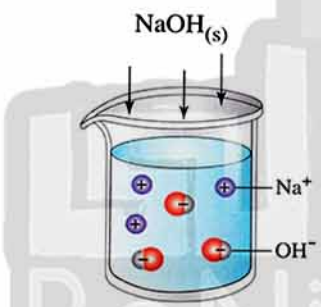
1 Classification of bases according to their strength (degree of ionization)

☆ **Bases are classified according to their degree of ionization (dissociation) into :**

Strong bases

Strong bases

Bases which are completely ionized in water.



Strong base NaOH

- Their solutions are good conductors of electricity.
- They are considered as strong electrolytes.

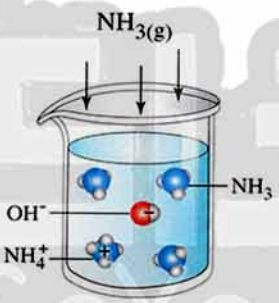
Examples

- Potassium hydroxide KOH
- Sodium hydroxide NaOH
- Barium hydroxide $Ba(OH)_2$

Weak bases

Weak bases

Bases which are incompletely ionized in water.



Weak base NH_3

- Their solutions are bad conductors of electricity.
- They are considered as weak electrolytes.

Example

- Ammonium hydroxide NH_4OH

2 Classification of bases according to their molecular structure

Bases are classified according to their molecular structure into :

Bases	Examples	Application
1. Metal oxides	Iron (II) oxide FeO Magnesium oxide MgO	$FeO_{(s)} + 2HCl_{(aq)} \xrightarrow{dil} FeCl_{2(aq)} + H_2O_{(l)}$ Iron (II) oxide — Hydrochloric acid — Iron (II) chloride — Water
2. Metal hydroxides	Calcium hydroxide $Ca(OH)_2$ Sodium hydroxide NaOH	$Ca(OH)_{2(aq)} + H_2SO_{4(aq)} \xrightarrow{dil} CaSO_{4(aq)} + 2H_2O_{(l)}$ Calcium hydroxide — Sulphuric acid — Calcium sulphate — Water
3. Metal carbonates	Potassium carbonate K_2CO_3 Sodium carbonate Na_2CO_3	$K_2CO_{3(s)} + 2HCl_{(aq)} \xrightarrow{dil} 2KCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$ Potassium carbonate — Hydrochloric acid — Potassium chloride — Water — Carbon dioxide
4. Metal bicarbonates	Potassium bicarbonate $KHCO_3$ Sodium bicarbonate $NaHCO_3$	$KHCO_{3(s)} + HCl_{(aq)} \xrightarrow{dil} KCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$ Potassium bicarbonate — Hydrochloric acid — Potassium chloride — Water — Carbon dioxide

Note

The bases that dissolve in water are called **Alkalis.**

Alkali

Alkali

It is a base that dissolves in water and gives hydroxide ion (OH^-).

Relation betwen alkalis and bases

So, the alkalis are a part of the bases and therefore, we can say that : all alkalis are bases and not all bases are alkalis.

Give reasons :

1. **Sodium carbonate is from bases.**
   Because sodium carbonate reacts with acid forming salt and water.
2. **Not all bases are alkalis.**
   Because there are some bases don't dissolve in water.

UNIT 3

Detecting acids and bases

- The aqueous solutions are divided into three types :
  - Acidic solutions.
  - Alkaline solutions.
  - Neutral solutions.

☆ **There are two methods for identifying these solutions :**

1. **Indicators.**
2. **pH-meter.**

1 Using the indicators for identifying the aqueous solutions

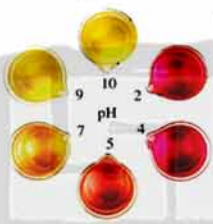
Indicators

They are weak organic acids or bases, their color changes with the change of the solution type.

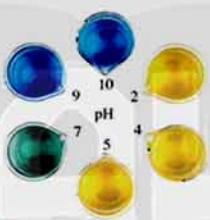
☆ **Indicators are used in :**

1. Identifying the type of solution.
2. Determining the end point in titration process between acids and bases.

☆ **The following table shows examples of some indicators and their colors in different media :**



Methyl orange



Bromothymol blue

Phenolphthalein

Indicators		Methyl orange	Bromothymol blue	Phenolphthalein	Litmus
The color in medium	Acidic (pH < 7)	Red	Yellow	Colorless	Red
	Neutral (pH ≈ 7)	Orange	Green	Colorless	Violet
	Basic (pH > 7)	Yellow	Blue	Pink	Blue

Enrichment information

Ant and bee bites have an acidic effect, and can be treated by using sodium bicarbonate solution, whereas the wasp and jelly fish have a basic effect and can be treated by using vinegar.

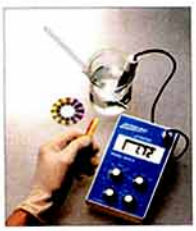
Give reasons :

1. **The color of indicator changes with the change of the solution type.**
   Because the color of non-ionized indicator is different from the color of ionized indicator in different solutions.
2. **Phenolphthalein can't be used to differentiate between the acidic and the neutral medium.**
   Because it has the same color (colorless) in the both media.

2 Using the hydrogen exponent pH for identifying the aqueous solutions

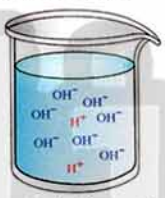
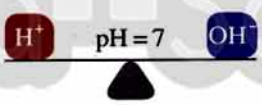
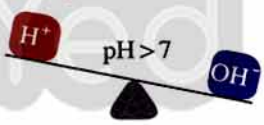
The hydrogen exponent pH

It is a way to express the degree of acidity or alkalinity of a solution.

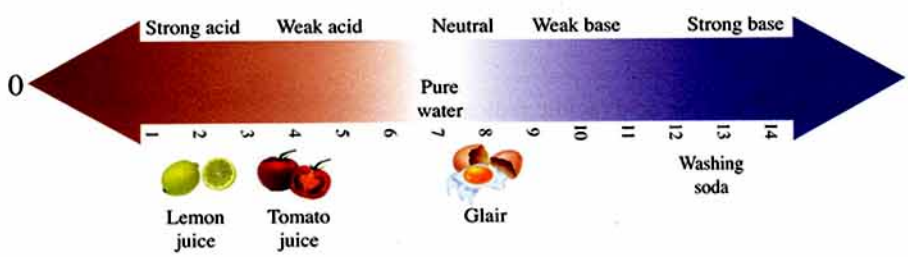


pH-meter and pH paper tape

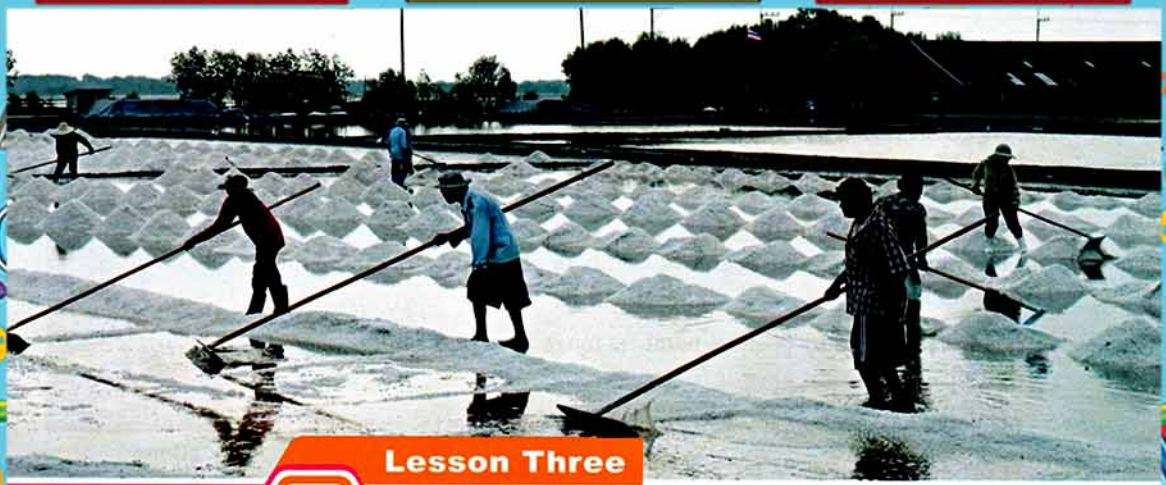
- pH value expressed by positive numbers range from 0 to 14
- pH value can be detected by :
  - pH paper tape.
  - pH-meter.
- The pH value depends on the concentration of positive hydrogen ions (H^+) and negative hydroxide ions (OH^-) in the solution, as follows :

Acidic solution	Neutral solution	Basic solution
When the monobasic acid dissolves in water, each molecule gives one proton H^+	When NaCl dissolves in water.	When NaOH dissolves in water, each molecule gives one hydroxide ion.
		
The concentration of $H^+ > OH^-$	The concentration of $H^+ = OH^-$	The concentration of $OH^- > H^+$
pH value < 7	pH value = 7	pH value > 7
		

☆ The following figure represents the pH - scale :



- Vinegar, lemon and tomato juices are acidic solutions (pH < 7).
- Washing soda, detergents and glair are basic substances (pH > 7).



Lesson Three

Chapter 2

Salts

Salts

Salts are abundantly found in Earth's crust.

They are also found dissolved in seawater.

Salt formation :

Cation

A positive ion (M^+) of the base (basic radical).

Anion

A negative ion (X^-) of the acid (acidic radical).

Combine together → Salt $M^+ X^-$

Example

Formation of potassium nitrate salt :

Cation (basic radical) → K^+ NO_3^- ← Anion (acidic radical)

- When potassium hydroxide reacts with nitric acid, potassium nitrate salt is produced :

$$\underset{\text{Potassium hydroxide}}{K^+OH^-_{(aq)}} + \underset{\text{Nitric acid}}{H^+NO^-_{3(aq)}} \xrightarrow{\text{dil}} \underset{\text{Potassium nitrate}}{K^+NO^-_{3(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

The chemical formula of salts and its naming

Rule	Example
• Reading of the chemical name of the mineral salt doesn't differ from the organic salt, as follows : • The chemical name of salts formed from two parts. • The first part refers to the basic radical (cation), while the second part refers to the acidic radical (anion).	Sodium chloride Potassium acetate
• The chemical formula of mineral salt differs from that of organic salt. – In the case of mineral salt the basic radical is written firstly, then the acidic radical. – In the case of organic salt the acidic radical is written firstly, then the basic radical.	Salt of mineral acid: Basic radical K^+ Potassium; Acidic radical NO_3^- nitrate Salt of organic acid: Acidic radical CH_3COO^- Potassium acetate; Basic radical K^+
• If the salt contains hydrogen in its acidic radical, we have to add either : – (Bi) or (hydrogen) before the name of its acidic radical.	$Na^+ HSO_4^-$ Sodium bisulphate or Sodium hydrogen sulphate
• In the case of metals that have more than one valence, we have to write a Latin number (I , II , III) which refers to the valence of the metal.	$Fe^{2+}SO_4^{2-}$ Iron (II) sulphate $Fe_2^{3+}(SO_4)_3^{2-}$ Iron (III) sulphate

UNIT 3

☆ The chemical formula of the salt depends on :

- The acid which represents the source of the anion.
- The valence of the anion and cation.

The acid	Anion	Cation	Salt	
HNO_3 Nitric acid	NO_3^- Nitrate anion	K^+	Potassium nitrate KNO_3	Nitrate Salts
		Pb^{2+}	Lead (II) nitrate $Pb(NO_3)_2$	
		Fe^{3+}	Iron (III) nitrate $Fe(NO_3)_3$	
HCl Hydrochloric acid	Cl^- Chloride anion	Na^+	Sodium chloride NaCl	Chloride Salts
		Mg^{2+}	Magnesium chloride $MgCl_2$	
		Al^{3+}	Aluminum chloride $AlCl_3$	
CH_3COOH Acetic acid	CH_3COO^- Acetate anion	K^+	Potassium acetate CH_3COOK	Acetate Salts
		Cu^{2+}	Copper (II) acetate $(CH_3COO)_2Cu$	
		Fe^{3+}	Iron (III) acetate $(CH_3COO)_3Fe$	
H_2SO_4 Sulphuric acid	SO_4^{2-} Sulphate anion	Na^+	Sodium sulphate Na_2SO_4	Sulphate Salts
		Cu^{2+}	Copper (II) sulphate $CuSO_4$	
	HSO_4^- Bisulphate anion	Na^+	Sodium bisulphate $NaHSO_4$	Bisulphate Salts
		Al^{3+}	Aluminum bisulphate $Al(HSO_4)_3$	
H_2CO_3 Carbonic acid	CO_3^{2-} Carbonate anion	Na^+	Sodium carbonate Na_2CO_3	Carbonate Salts
		Ca^{2+}	Calcium carbonate $CaCO_3$	
	HCO_3^- Bicarbonate anion	Na^+	Sodium bicarbonate $NaHCO_3$	Bicarbonate Salts
		Mg^{2+}	Magnesium bicarbonate $Mg(HCO_3)_2$	

Give reason :

$FeCl_3$ is named as iron (III) chloride, while $AlCl_3$ is aluminum chloride, although the valence of iron and aluminum is 3 in the two salts.

Because iron has two valencies (II , III), while aluminum has only one valence (III).

From the previous table we can conclude that :

Some acids have more than one type of salts, due to the number of hydrogen atoms in the acid molecule.

- **Monobasic acids form only one type of salts like :**
  1. Nitric acid HNO_3 ⟶ forms nitrate salts only.
  2. Hydrochloric acid HCl ⟶ forms chloride salts only.
  3. Acetic acid CH_3COOH ⟶ forms acetate salts only.

CH_3COO^-

Acetate group

- **Dibasic acids form two types of salts like :**
  1. Sulphuric acid H_2SO_4 ⟶ forms sulphate and bisulphate salts.
  2. Carbonic acid H_2CO_3 ⟶ forms carbonate and bicarbonate salts.

CO_3^{2-}

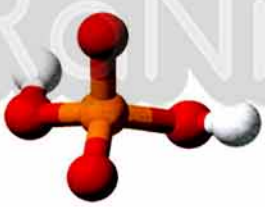
Carbonate group

HCO_3^-

Bicarbonate group

- **Tribasic acids form three types of salts like :**

Phosphoric acid (H_3PO_4) forms three types of salts :

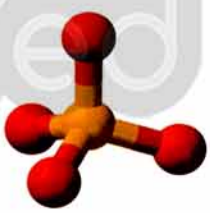


$H_2PO_4^-$

Dihydrogen phosphate group

HPO_4^{2-}

Hydrogen phosphate group



PO_4^{3-}

Phosphate group

Questions :

- **Use the following radicals to write the chemical formulas of some salts, then write their names.**

$(Ba^{2+} / Ca^{2+} / NH_4^+ / NO_3^- / SO_4^{2-} / Cl^-)$

UNIT 3

Answer

Acidic radical / Basic radical	NO_3^- Nitrate	SO_4^{2-} Sulphate	Cl^- Chloride
Ba^{2+} Barium	$Ba(NO_3)_2$ Barium nitrate	$BaSO_4$ Barium sulphate	$BaCl_2$ Barium chloride
Ca^{2+} Calcium	$Ca(NO_3)_2$ Calcium nitrate	$CaSO_4$ Calcium sulphate	$CaCl_2$ Calcium chloride
NH_4^+ Ammonium	NH_4NO_3 Ammonium nitrate	$(NH_4)_2SO_4$ Ammonium sulphate	NH_4Cl Ammonium chloride

Salts formation methods

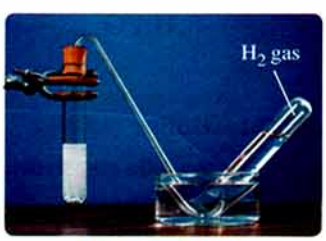
Salts can be practically prepared by one of the following methods :

1. **Reaction of active metals with diluted acids.**
2. **Reaction of metal oxides with acids.**
3. **Reaction of metal hydroxides with acids.**
4. **Reaction of metal carbonates or bicarbonates with some acids.**

1 Reaction of active metals with diluted acids

$$\text{Active metal} + \text{Acid} \xrightarrow{\text{dil}} \text{Salt of acid} + \text{Hydrogen gas}\uparrow$$

- The metals above hydrogen in the chemical activity series replace hydrogen in the diluted acid solutions, giving salt of acid and hydrogen gas is evolved which burns with a pop sound.
- The salt of acid which is produced dissolves in water and can be separated by heating the solution, where the water evaporates and the salt remains.



H_2 gas evolved

Example

Reaction of zinc with diluted sulphuric acid.

$$\underset{\text{Zinc}}{Zn_{(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \xrightarrow{\text{dil}} \underset{\text{Zinc sulphate}}{ZnSO_{4(aq)}} + \underset{\text{Hydrogen gas}}{H_{2(g)}\uparrow}$$

2 Reaction of metal oxides with acids

Metal oxide + Acid $\xrightarrow{\text{dil}}$ Salt of acid + Water

- This method is used if there is a difficulty in the direct reaction of metal with acid because :
  - The reaction is dangerous (**e.g.** reaction of sodium with hydrochloric acid is vigorous).
  - The metal doesn't react with the acid, because it is less reactive than hydrogen (**e.g.** copper doesn't react with hydrochloric acid).

Copper doesn't react with hydrochloric acid

Example

Reaction of copper oxide with sulphuric acid.

$$\underset{\text{Copper oxide}}{CuO_{(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \xrightarrow{\text{dil}} \underset{\text{Copper sulphate}}{CuSO_{4(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

3 Reaction of metal hydroxides with acids

- This method is suitable in the case of metal hydroxides, that are dissolving in water and considered as alkalis.
- These types of reactions are known as **"Neutralization reactions"**.
- Neutralization reaction can be used in analytical chemistry to calculate the concentration of an acid (or an alkali) using a known concentration of a base (or an acid) in the presence of a suitable indicator.

Titration process by using a suitable indicator

UNIT 3

Neutralization point (End point)

It is the moment at which the amount of acid is equivalent to the amount of alkali.

Metal hydroxide (alkali) + Acid $\xrightarrow{\text{dil}}$ Salt of acid + Water

Example

$NaOH_{(aq)}$ + $HCl_{(aq)}$ $\xrightarrow{\text{dil}}$ $NaCl_{(aq)}$ + $H_2O_{(l)}$

Sodium hydroxide + Hydrochloric acid → Sodium chloride + Water

4 Reaction of metal carbonates or bicarbonates with some acids

Metal carbonate (or bicarbonate) + Acid → Salt of acid + Water + Carbon dioxide gas ↑

- Metal carbonates or bicarbonates are salts of carbonic acid which is an unstable acid, due to its low boiling point.
- It is possible for any other acid (that is more stable than it) to remove it from its salt solutions to form a new acid salt.
- Carbonic acid decomposes into water and carbon dioxide gas, which turns the clear limewater into milky.

Example

Reaction of sodium carbonate with hydrochloric acid.

$Na_2CO_{3(s)}$ + $2HCl_{(aq)}$ → $2NaCl_{(aq)}$ + $H_2O_{(l)}$ + $CO_{2(g)}\uparrow$

Sodium carbonate + Hydrochloric acid → Sodium chloride + Water + Carbon dioxide gas

Give reason :

The reaction of metal carbonates or bicarbonates with some acids is called "Acidity test".

Because this reaction is used to detect the presence of acids, as a strong effervescence occurs and CO_2 gas evolves, which turns the clear limewater into turbid.

Types of aqueous solutions of salts

Base (+)	Acid (→)	Salt	Salt solution
NaOH (strong)	HCl (strong)	NaCl	neutral pH = 7
NH_4OH (weak)	CH_3COOH (weak)	CH_3COONH_4	
NH_4OH (weak)	HCl (strong)	NH_4Cl	acidic pH < 7
NaOH (strong)	H_2CO_3 (weak)	Na_2CO_3	basic pH > 7

Give reasons :

1 The aqueous solution of sodium chloride is neutral.

Because NaCl is produced from the reaction between a strong acid (HCl) and a strong base (NaOH). So, the pH value is 7

2 The aqueous solution of sodium carbonate is basic.

Because Na_2CO_3 is produced from the reaction between a strong base (NaOH) and a weak acid (H_2CO_3). So, its pH value > 7

3 The pH value of an aqueous solution of ammonium chloride is less than 7

Because this solution is acidic, where NH_4Cl is produced from the reaction between a strong acid (HCl) and a weak base (NH_4OH).

4 The pH value of an aqueous solution of ammonium acetate equals 7

Because this solution is neutral, where CH_3COONH_4 is produced from the reaction between a weak acid (CH_3COOH) and a weak base (NH_4OH).

Booklet model 1

The guiding model of the ministry of Education

Choose the correct answer for the questions 1 : 6

1 Which of the following solutions has higher boiling point ? .....

(a) 1 M sodium carbonate.

(b) 2 M sodium carbonate.

(c) 1 M iron (III) chloride.

(d) 2 M iron (III) chloride.

2 Number of atoms in half a mole of formaldehyde HCHO equals .....

(a) Avogadro's number.

(b) $\frac{1}{2}$ Avogadro's number.

(c) 2 × Avogadro's number.

(d) $\frac{1}{4}$ Avogadro's number.

3 On dissolving 55.5 g of calcium chloride $CaCl_2$ in water to form a solution its volume = 0.5 L , the concentration of this solution equals ..... [Ca = 40 , Cl = 35.5]

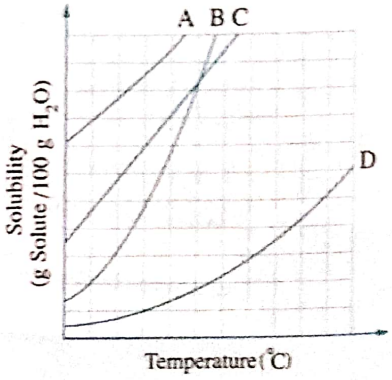
(a) 1 M (b) 0.5 M (c) 2 M (d) 1.5 M

4 An experiment was carried out to find the molecular formula of an unknown compound which contains three elements (A), (B) and (C), it was found that the mass percentage of the element (A) is 40% and that of the element (B) is 12%, what is the molecular formula of this compound, Knowing that it is also the empirical formula ? ..... [A = 40 , B = 12 , C = 16]

(a) ABC_3 (b) A_3BC

(c) AB_3C (d) A_2B_2C

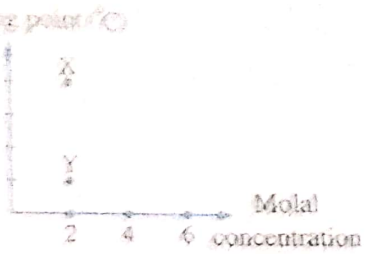
5 The opposite graph represents the relation between the solubility of some substances and the temperature, which of these substances its solubility increases with a higher extent by increasing the temperature of the solvent ? .....



(a) A (b) B

(c) C (d) D

7 In the opposite graph, if the solutions (X), (Y) have the same molal concentration, So the solution (X) is ..... and the solution (Y) is .....



(a) sodium chloride solution / glucose solution.
(b) sodium chloride solution / aluminum nitrate solution.
(c) potassium carbonate solution / aluminum nitrate solution.
(d) potassium carbonate solution / glucose solution.

8 Through the following radicals :

CH_3COO^- SO_4^{2-} Na^+ NH_4^+

Deduce the chemical formula of the salt, which dissolves in water forming a solution with pH value higher than 7

pH > 7 ∴ So Solution is alkaline.
CH_3COONa (Sodium acetate)
CH_3COO^- => weak acid ..... acetic acid
Na^+ => Strong base (NaOH)

9 Arrange the following acids ascendingly according to their number of basicity :

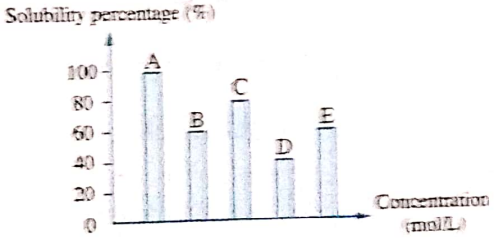
H_3BO_3 / HCN / H_2SO_3

HCN < H_2SO_3 < H_3BO_3

10 Deduce the conjugate acid and the base according to Brönsted - Lowry theory in the following equation : $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

H_3O^+ => Conjugate acid ..... H_2O => base

11 In the opposite graph Which of the illustrated compounds (A, B, C, D, or E) represents the ionization of an organic acid in water ? Why ?



Compound (D) as organic acid are weak acids, that are not completely ionized in water

11 Calculate the number of moles of iron (III) oxide Fe_2O_3 produced from heating 456 g of iron (II) sulphate $FeSO_4$ according to the equation : [Fe = 56 , S = 32 , O = 16]

$$2FeSO_4 \xrightarrow{\Delta} Fe_2O_3 + SO_2 + SO_3$$

2mole → 1mole

304 → 1mole

456 → ?

$? = \frac{456}{304}$ mole

2mole → 1mole

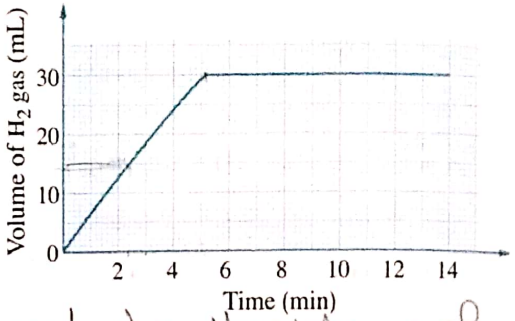
2(56+32+64) → 160

304 → 160

456 → ?

$? = \frac{456 \times 160}{304} = 204gm \Rightarrow$ no. mole $= \frac{204}{160} = 1.5$ mole

12 The opposite graph represents the relation between the volume of hydrogen gas which is evolved from the reaction of a limited amount of magnesium with excess of hydrochloric acid by time, deduce the time of consumption of half the amount of magnesium.



All amount of magnesium is consumed when the volume of hydrogen gas become constant (30 mL) at 5 min

half amount of magnesium consumed when H_2 gas become (15 mL) after ⇒ 2.4 min

Booklet model 2

Choose the correct answer for the questions (1) : (10). (10 marks)

1 Which of the following measuring relations is incorrect ? .....

(a) 1 microliter = 1×10^{-6} L

(b) 1 gram = 1×10^{-6} kg

(c) 1 liter = 10^{3} mL

(d) 10^{2} centigram = 1 g

2 What is the mass percentage of hydrogen in chlorous acid $HClO_2$? .....

[H = 1 , Cl = 35.5 , O = 16]

(a) 1.92% (b) 25% (c) 23.4% (d) 1.46%

3 What is the number of nitrogen atoms in 240 g of ammonium nitrate ? ..... atoms.

[N = 14 , H = 1 , O = 16]

(a) 2×10^{23} (b) 6.02×10^{23} (c) 1.81×10^{24} (d) 36.12×10^{23}

4 What is the total number of moles of H^+ which are found in 2.5 L phosphoric acid its concentration is 0.7 M ? .....

(a) 0.233 mol (b) 2.1 mol (c) 5.25 mol (d) 3 mol

5 Which of the following solutions has higher boiling point ? .....

(a) 0.1 M HI solution. (b) 0.1 M $(NH_4)_3PO_4$ solution.

(c) 0.1 M NH_4Cl solution. (d) 0.1 M NaI solution.

6 Which of the following colloids is formed from dispersion of liquid in solid ? .....

(a) Hair gel, cheese and butter. (b) Milk, hair gel and blood.

(c) Aerosol, jelly and mayonnaise. (d) Mayonnaise, hair gel and cheese.

7 35.5 mL aqueous solution contains 22.5 g of sucrose (its molar mass = 342 g/mol)

What is the molar concentration of this solution ? .....

(a) 0.0657 M (b) 1.85×10^{-3} M (c) 1.85 M (d) 0.104 M

8 10 g of hydrogen gas react with excess of oxygen gas according to the equation :

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$$

What is the reacted volume of oxygen gas (at STP) and the mass of the produced water vapour in this reaction ? .....

Choices	Reacted volume of O_2	Mass of H_2O
(a)	2.5 L	5 g
(b)	5 L	5 g
(c)	56 L	90 g
(d)	80 L	120 g

9 Each of the following acids when dissolves in water, it can yield more than one proton, except .....

(a) oxalic acid. (b) sulphuric acid. (c) carbonic acid. (d) acetic acid.

10 What does happen when a small crystal of the solute substance is put in its supersaturated solution ? .....

(a) The crystal dissolves in the solution only.

(b) The solution becomes saturated only.

(c) The molecules of the solute will be collected around the crystal only.

(d) (b) , (c) together.

11 "Carbon is found in the form of graphite and diamond",

Mention three other forms in which carbon can be found.

Singleaton — Carbon nanotubes — Bucky ball

1 mark

12 Calculate the molar mass of calcium phosphate compound. [Ca = 40 , P = 31 , O = 16]

$Ca_3(PO_4)_2$ = (3×40) + (2×31 + 64)

120 + 190 = 310 g/mol

1 mark

13 Complete the following equation, and rewrite it in the form of an ionic equation :

$$Fe(NO_3)_{2(aq)} + (NH_4)_2CO_{3(aq)} \longrightarrow FeCO_{3(s)} + 2NH_4NO_{3(aq)}$$

$$Fe^{2+} + 2NO_3^- + 2NH_4^+ + CO_3^{2-} \longrightarrow FeCO_3 + 2NH_4^+ + 2NO_3^-$$

$$Fe^{2+} + CO_3^{2-} \longrightarrow FeCO_{3(s)}$$

2 marks

14 What is the type of the aqueous solution of sodium nitrate salt (acidic, basic or neutral) ? Explain.

Neutral, as it salt Produced from reaction between strong acid (HNO_3) and strong base (NaOH)

2 marks

15 In this reaction : $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH^+_{4(aq)} + OH^-_{(aq)}$

What does each of the following represent in the light of Lewis concept of acids and bases :

(1) Ammonia gas.

Lewis base as it donor with a pair of electron

(2) Water.

Lewis acid as it accepts a pair of electron

1 mark

16 Sulphuric acid is added to barium hydroxide until the reaction is completed, write the symbolic equation which represents this reaction, with illustrating the physical state of barium hydroxide only in this reaction, then explain which is larger in number :

the ions which are present in the beginning of the reaction or the ions which are present at the end of the reaction ?

$Ba(OH)_{2(aq)} + H_2SO_4 \longrightarrow BaSO_{4(s)} + 2H_2O$

The greater number of ions at the beginning of reaction as Ba^{2+}, SO_4^{2-} leave the reaction and precipitate at the end of reaction

2 marks

17 Calculate the percentage of the actual yield of zinc sulphate, if its calculated (theoretical) mass = 1.358 g and its actual mass = 1.146 g

% actual yield $= \frac{\text{actual mass}}{\text{Theoritical mass}} \times 100$

$= \frac{1.146}{1.358} \times 100 = 84.39\ \%$

1 mark

Booklet model 3

Rate your level

★★★★ Superior		★★★ Remarkable		★★ above average		Weak
from	to	from	to	from	to	less then
20 marks	18 marks	17 marks	14 marks	13 marks	10 marks	10 marks

Choose the correct answer for the questions 1 : 10 . (10 marks)

1 In bucky ball, every carbon atom is attached to ..... other carbon atoms.

(a) 1 (b) 2 (c) 3 (d) 4

2 Each of the following is a solution, except .....

(a) iron filings with sulphur powder. (b) hydrogen chloride gas in water.
(c) iodine in benzene. (d) silver in mercury.

3 Two closed vessels contain chlorine gas at the same conditions of temperature and pressure, so if the first vessel whose volume = 1.3 L contains 6.7 mol of gas, what is the number of moles in the second vessel whose volume = 2.33 L ? .....

(a) 0.452 mol (b) 3.74 mol (c) 12 mol (d) 20.3 mol

4 Which of the following aqueous solutions has lower freezing point ? .....

(a) 0.1 m $(NH_4)_2SO_4$ (b) 0.1 m $MnSO_4$
(c) 0.1 m NaF (d) 0.1 m CH_3OH

5 In which of these choices $H_2PO_4^-$ acts as an acid ? .....

(a) $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$

(b) $H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$

(c) $H_2PO_4^- + OH^- \rightleftharpoons H_3PO_4 + O^{2-}$

(d) An ion can't act as an acid in any chemical reaction.

6 All of the following are colloids, except .....

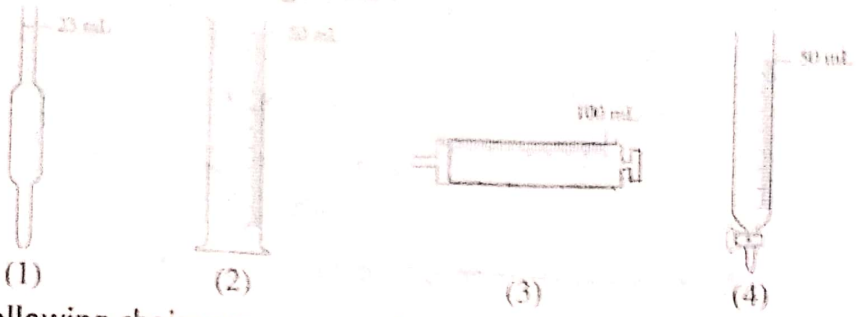
(a) air in whipped egg whites. (b) air in cotton candy.
(c) ground maize powder in water. (d) oxygen in atmospheric air.

7 Molal solution contains 1 mol of the solute in .....

(knowing that water density = 1 kg/L)

(a) 1000 mL of the solvent. (b) 1000 g of the solution.
(c) 1 L of water. (d) 22.4 L of the solution.

8 Here are four different measuring tools :



(1) (2) (3) (4)

Which of the following choices represents the proper use for the measuring tool ? .....

Choices	Measuring tool	Used in
(a)	(1)	Transferring 20 mL of an alkali to carry out a titration.
(b)	(2)	Collecting 75 mL of the gas produced from a thermal decomposition reaction.
(c)	(3)	Adding 1 mL of an acid to calcium carbonate.
(d)	(4)	Adding 15.6 mL of an acid to carry out a titration.

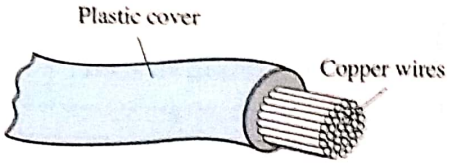
9 On dissolving NH_4ClO_4 acid in water, the formed solution is ..... NH4OH weak , HClO4 Perchloric acid

(a) acidic. (b) neutral. (c) basic. (d) amphoteric.

10 What is the meaning of that nitric acid is a strong acid ? .....

(a) It dissolves in water and H^+ concentration in the solution equals OH^- concentration.
(b) It does not ionize in water on dissolving in it.
(c) It ionizes completely in water into H^+, NO_3^- ions.
(d) It is neutralized by a strong base only.

11 The opposite figure represents a section in a flexible copper cable, it easily bends with the bends of the plastic pipes inside walls and ceilings, is it useful to replace copper which is used in the manufacture of cable wires with any of the following ? Explain your answer.



(1) Copper nano wires.

No, Bec, The hardness of copper increase by decreasing volume of its particles to nano scale and it can't be bend

(2) Single - wall carbon nano tubes.

Yes, as the ability of carbon nano tubes to conduct electricity is larger than Copper

2 marks

12 **Calculate the mass of oxygen** in 0.52 g of sodium bicarbonate.

[Na = 23 , H = 1 , C = 12 , O = 16]

$NaHCO_3 \longrightarrow 3O$

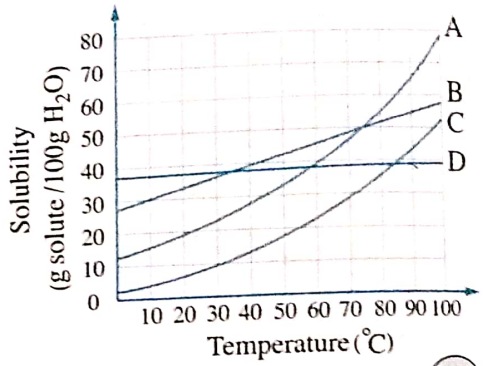
$(23+1+12+48) \longrightarrow 3\times16$

$0.52 \longrightarrow ?$

$? = \frac{0.52\times48}{84} = 0.297\ g$

1 mark

13 The opposite graph shows the solubility curve of four different substances A , B , C and D, **which of these substances its solubility is :**



(1) As high as possible at 10°C

(D)

(2) As low as possible at 90°C

(D)

1 mark

14 **Compare between** hydrogen chloride gas **and** glucose **by filling in the spaces in the following table :**

Points of comparison	Hydrogen chloride gas	Glucose
(1) **Solubility in water**	Soluble	Soluble
(2) **Ionization in water**	Complete ionization	Not ionized

1 mark

15 **Choose, with explanation,** one or more of the following substances that can be present in a test tube which contains phosphoric acid :

PO_4^{3-} HPO_4^{2-} $H_2PO_4^-$ H_3PO_4

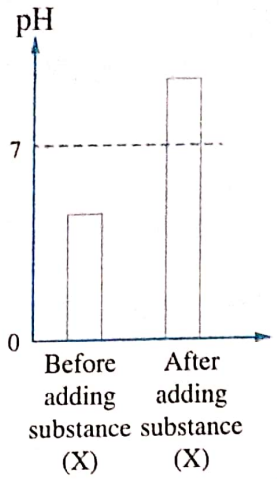
All of them, as phosphoric acid is a tribasic acid, which can present in form of molecules with ioniz

2 marks

16 The opposite graphical figure represents pH values of the wastes of a factory before and after adding substance (X),

What is the type of substance (X) ? Explain.

Basic Bec, it causes increasing in the pH value of wastes



1 mark

17 **Rewrite the following word equation as a balanced symbolic equation :**

Magnesium nitrate + Potassium phosphate ⟶ Magnesium phosphate + Potassium nitrate

$a Mg(NO_3)_2 + {}^{b}K_3PO_4 \longrightarrow {}^{c}Mg_3(PO_4)_2 + {}^{d}KNO_3$

2 marks

Mg ⇒ $a = 3c$

N ⇒ $2a = d$

O ⇒ $6a + 4b = 8c + 3d$

K ⇒ $3b = d$

P ⇒ $b = 2c$

$a = 1$, $c = \frac{1}{3}$, $b = \frac{2}{3}$, $d = 2$ ×3 ⇒ $a = 3$, $c = 1$, $b = 2$, $d = 6$

$3Mg(NO_3)_2 + 2K_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 6KNO_3$

Booklet model 4

Rate your level

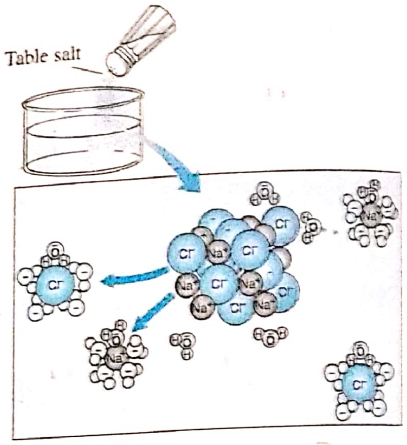
★★★★ Superior	★★★ Remarkable	★★ above average	less than 6 marks
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	

Choose the correct answer for the questions 1 : 10 .

1 The screen of the mobile phone is covered with nano liquid to form a thin layer on its surface to protect it from scratching and breaking, what is the type of the material used in manufacture of this nano liquid ? .....

(a) Colloidal substance.
(b) One-dimensional nano substance.
(c) Suspension substance.
(d) Two-dimensional nano substance.

2 Which of the following equations represents the process of dissolving the table salt in water which is illustrated in the figure ? .....



(a) $NaCl_{(aq)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$
(b) $NaCl_{(s)} \xrightarrow{water} Na^+_{(s)} + Cl^-_{(s)}$
(c) $NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$
(d) $NaCl_{(aq)} \xrightarrow{water} Na^+_{(s)} + Cl^-_{(g)}$

3 The ionic equation which represents the reaction of sodium hydroxide solution with hydrochloric acid does not contain each of .....

(a) Na^+ , Cl^- (b) H^+ , OH^- (c) Na^+ , OH^- (d) H^+ , Cl^-

4 In the following reaction : $6Li_{(s)} + N_{2(g)} \longrightarrow 2Li_3N_{(s)}$
What is the number of moles of lithium required to react with excess of nitrogen gas to produce 0.6 mol of lithium nitride ? .....

$6Li \rightarrow 2Li_3N$
6 mole $\rightarrow$ 2 mol
? $\rightarrow$ 0.6 mol

(a) 0.2 mol (b) 0.3 mol (c) 0.4 mol (d) 1.8 mol

5 Each of the following is among the properties of lactic acid, except that it .....

(a) is found in yaughurt.
(b) is an organic acid.
(c) reacts with sodium to form salt and water.
(d) is a weak acid.

6 The following compounds formulas :

$$KNO_3 , Pb(NO_3)_2 , Fe(NO_3)_3$$

indicate that the nitrate group is .....

(a) monovalent only.
(b) divalent only.
(c) trivalent only.
(d) mono, di, and trivalent.

7 Which of the following examples is an application of Avogadro's law ? .....

(a) When 3 balloons contain equal numbers of H_2 , O_2 and Cl_2 molecules, their volumes will be equal at the same temperature and pressure.
(b) The balloon which contains H_2 gas, its volume increases by increasing temperature at constant pressure.
(c) The volume of a balloon decreases with decreasing the number of moles of Ar gas in it at constant temperature and pressure.
(d) The volume of a piston which contains neon decreases by increasing the pressure at constant temperature.

8 In the opposite table
Water that contains a little amount of acetone, its boiling point is .....

Substance	Boiling point
Acetone	56°C
water	100°C

(a) 56°C
(b) 78°C
(c) 100°C
(d) 104°C

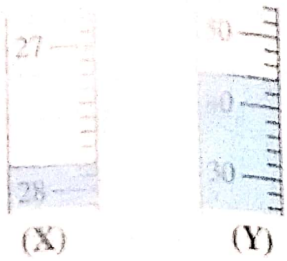
9 Which of the following choices represents dissolving table sugar (its molar mass = 342 g/mol) in water and dissolving table salt (its molar mass = 58.5 g/mol) in water ? .....

(a) Both form liquid in solid solutions.
(b) Both are electrolytes.
(c) Freezing point of the salt solution is lower than the freezing point of sugar solution at the same concentration.
(d) On adding x mass of each to the same volume of water, sugar solution concentration will be higher than that of salt solution.

10 On neutralizing acetic acid with sodium hydroxide solution, ... is formed.

(a) alkaline solution.
(b) acidic solution.
(c) neutral solution.
(d) gaseous solution.

11 The opposite figures (X) , (Y) represent two sections in two measuring tools :



- **Tool (X) :** is used in measuring a definite volume of an acid accurately.
- **Tool (Y) :** is used in estimating the increase in the volume of water on dipping a piece of iron in it,

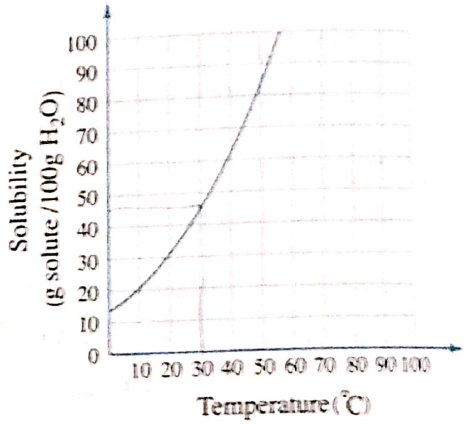
what is the name of each tool ? What is the volume of the measured liquid in each of them ?

X = Burette , volume = 27.8 ml

Y => Graduated cylinder => 44 ml

1 mark

12 In the opposite figure which represents the solubility curve of potassium nitrate in water, on stirring 75 g of potassium nitrate in 100 g of water at 100°C, no precipitate is formed and when the solution is cooled to 30°C a precipitate appears.



What is the type of solution (unsaturated / saturated / supersaturated) ? Explain your answer and calculate the precipitated mass of potassium nitrate after cooling to 30°C approximately.

Supersaturated as on cooling the solution, the excess solute particles precipitated.

Quantity = 75 - 45 = 30 gm

2 marks

13 Calculate the mass percentage of carbon in oxalic acid. [C = 12 , O = 16 , H = 1]

COOH
|
COOH → 2C

[(2X12) + (2X2X16) + (2X1)] → 2X12

90 gm = 24 gm

Percentage = $\frac{24}{90}$ X100 = 26.67 %

1 mark

14 One of the students carried out an experiment to find out the type of the mixture formed by shaking mercury in petroleum oil.

Experiment	Observation
(1) On falling a beam of light on the mixture	The light is scattered
(2) On leaving the mixture for some minutes after shaking	Mercury precipitates in oil
(3) On pouring the mixture in a funnel contains a filter paper	Mercury is separated from oil

Depending on these observations, recognize the type of this mixture, with explaining.

- Is it a solution ?

not Solution, as Solution isn't Scattering the light falling on it while mixture do.

- Is it a colloid ?

not Colloid, as Colloid Particles don't precipitates after Shaking and it Components Can't be separated by filtration

- Is it a suspension ?

Yes, as Suspension Scatters light and its Particles precipitates after Shaking and can Separate by filtration

2 marks

15 **Illustrate by a symbolic equation only** the definition of an acid in the light of Arrhenius theory, **what is the change that happens** in water which contains some drops of methyl orange indicator by adding the acid to it ?

$HNO_3 \longrightarrow H^+ + NO_3^-$

by adding acid to methyl orange it's Color change into red

1 mark

16 Among the famous chemical compounds :

• Iron (II) oxide. FeO • Calcium oxide. CaO

(1) Illustrate by symbolic equations only a similarity between the two compounds.

$FeO_{(s)} + 2HCl_{(aq)} \rightarrow FeCl_{2(aq)} + H_2O_{(l)}$

$CaO_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)}$

Both of them are metal oxide which are basic oxide and react with acid gives salt + water

(2) Why is iron (II) oxide described as a base and not an alkali, while calcium oxide is described as a base and an alkali ?

FeO is base as it not soluble in water

While CaO is a base and alkali as it dissolves in water

2 marks

17 Calculate the molar concentration of a solution of the table salt its volume = 1.5 L and contains 26.325 g of sodium chloride where its molar mass = 58.5 g/mol

$$\text{No. moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{26.325}{58.5} = 0.45 \text{ mol}$$

$$\text{Mararity} = \frac{\text{no. moles}}{\text{volume of Solution}} = \frac{0.45}{1.5} = 0.3 \text{ M}$$

1 mark

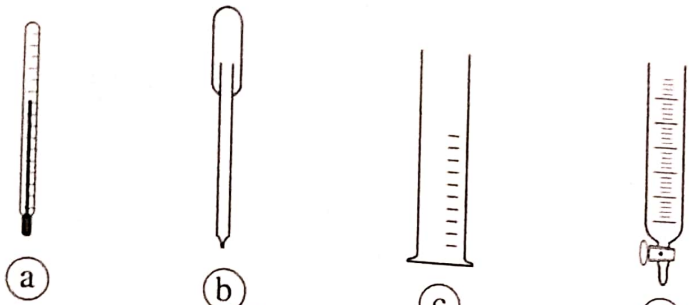
Booklet model 5

Rate your level

Superior	Remarkable	above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

Choose the correct answer for the questions 1 : 10 . (10 marks)

1 Which of the following tools shown in figures can be used to transfer the highly dangerous liquids ? .....



(a) (b) (c) (d)

2 You have four solutions of equal concentrations, which of them conducts electric current by a higher degree ? .....

(a) HF (b) HBr (c) HCN (d) H_2SO_3

3 Nitric acid is similar to acetic acid in that both are ..... acids.

(a) organic (b) mineral (c) strong (d) monobasic

4 What is the empirical formula of the compound that contains 85.6% carbon and 14.4% hydrogen ? .....

[C = 12 , H = 1]

(a) CH (b) CH_2 (c) CH_3 (d) CH_4

5 Which of the following is not a strong base ? .....

(a) $Ca(OH)_2$ (b) KOH (c) NH_3 (d) LiOH

6 What is the mass of solute in a solution of ammonium chloride, its volume is 256 mL and its concentration is 0.9 M ? .....

[N = 14 , H = 1 , Cl = 35.5]

(a) 12.3 g (b) 16.3 g (c) 175 g (d) 215 g

7 What is the number of types of salts that phosphoric acid can form ? .....

(a) 1 (b) 2 (c) 3 (d) 4

8 In the following equation :

$$C_6H_5NH_{2(aq)} + H_2O_{(l)} \rightleftharpoons C_6H_5NH^+_{3(aq)} + OH^-_{(aq)}$$

Reactants and products can be classified as follows : .....

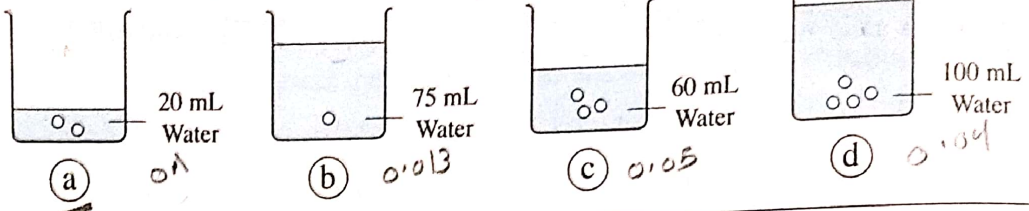
(a) acid + base $\rightleftharpoons$ acid + base. (b) acid + base $\rightleftharpoons$ base + acid.

(c) base + acid $\rightleftharpoons$ acid + base. (d) base + acid $\rightleftharpoons$ base + acid.

9 The following acids : (H_3PO_4 / HCl / H_2SO_3)
are arranged from weaker to stronger as follows : .....

(a) $HCl < H_3PO_4 < H_2SO_3$
(b) $HCl < H_2SO_3 < H_3PO_4$
(c) $H_2SO_3 < H_3PO_4 < HCl$
(d) $H_3PO_4 < H_2SO_3 < HCl$

10 Which of the following solutions is more saturated ? .....



(a) 0.1 (b) 0.013 (c) 0.05 (d) 0.004

11 The opposite figure shows a nanorobot that Dr. Magdi Yacoub dreams to use in his field to carry out operations without surgery.

Suggest an importance for the nanorobot.
removing blood clots from blood vessels, when it is introduced to blood stream without surgery

1 mark

12 Calculate the mass of each of solute and solvent in potassium chloride solution its mass is 250 g and its concentration is 5%

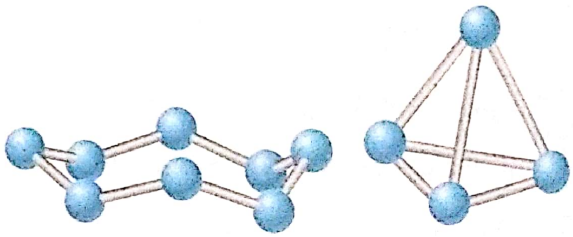
% (m/m) = $\frac{\text{mass of solute}}{\text{mass of solution}} \times 100$

mass of solute = $\frac{\%\,(m/m) \times \text{mass of solution}}{100} = \frac{5 \times 250}{100} = 12.5$ gm

mass of solvent = mass of solution − mass of solute = 250 − 12.5 = 237.5 gm

2 marks

13 The opposite two figures represent the structure of phosphorus and sulphur vapours (with no particular order) if you know that the gram atomic mass of phosphorus is 31 g/mol and that of sulphur is 32 g/mol :



(X) (Y)

(1) Which figure represents the structure of phosphorus vapour molecule ?
figure (Y)

(2) Calculate the molar mass of the vapour of the two elements.
$S_8 = 8 \times 32 = 256$ gm/mol
$P_4 = 4 \times 31 = 124$ gm/mol

1 mark

14 Complete the following table with what is suitable of the following substances :

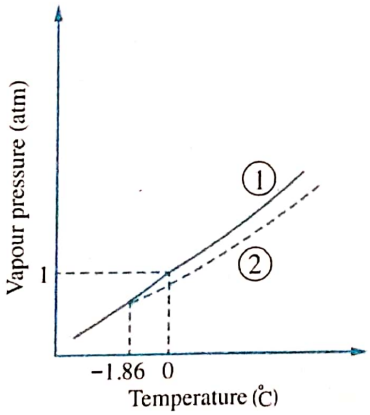
Gas | Liquid | Solid | Nickel chrome alloy | Atmospheric air | Sea water

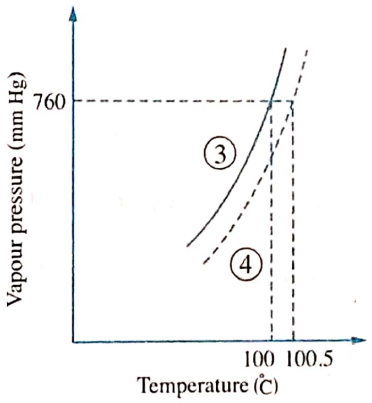
Types of solution	Physical state of solute	Physical state of solvent	Example
(1) Gaseous solution	Gas	Gas	air
(2) Liquid solution	Solid	Liquid	Sea water
(3) Solid solution	Solid	Solid	nickel Chrome alloy

2 marks

15 In the light of your knowledge about the relation between the vapour pressure and each of boiling and freezing points of each of pure water and the solution, replace the numbers shown on the following figures with what suits each of them from the terms :

- Pure water.
- The solution.





(1) Pure water (2) Solution

(3) Pure water (4) Solution

1 mark

16 The following ions can form several salts :

Na^+ | NH_4^+ | Cl^- | CO_3^{2-}

Conclude the chemical formula of the salt that dissolves in water forming :

(1) A solution its pH equals 7 (NaCl)

(2) A solution its pH is less than 7 (NH_4Cl)

(3) A solution its pH is more than 7 (Na_2CO_3)

2 marks

17 **Calculate the mass percentage** of hydrogen [H = 1] in magnesium bicarbonate compound, its molar mass is 146 g/mol

$Mg(HCO_3)_2 \longrightarrow 2H$

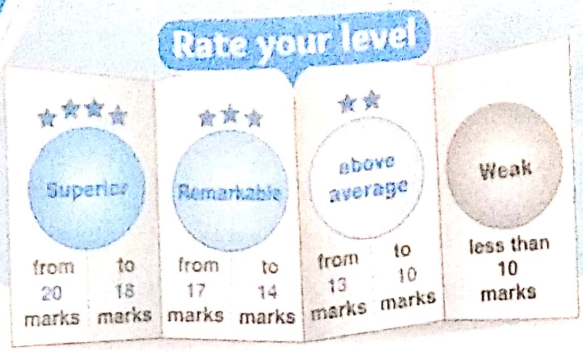
146 g ⟶ 2 g

1 mole ⟶ 2 mole

mass of H = $\frac{\text{mass of (H) in 1 mole}}{\text{molar mass of compound}}$ $\frac{2}{146} \times 100 = 1.36\%$

1 mark

Booklet model 6



Choose the correct answer for the questions 1 : 10 . (10 marks)

1 Which of the following expresses a quantitative measurement ? .....

(a) Aluminum bar is longer than copper bar.

(b) The first solution is more concentrated than the second solution.

(c) The colour of the first solution is blue.

(d) The temperature of the second solution is 60°C (Quantity + magnitude)

2 Which of the following is an application of Avogadro's postulate ? .....

(a) oxygen atom is 16 times heavier than hydrogen atom.

(b) 1 cm^3 of each of Ar , O_2 , NH_3 gases contains the same number of molecules at 80k and 1 atm.

(c) Volume of hydrogen gas increases by increasing its number of moles at constant temperature and pressure.

(d) A mole of any gas such as CH_4 contains 22.4 L (at STP).

H_2S

3 What is the number of moles of hydrogen sulphide in 49.7 g sample of it ? .....

[S = 32 , H = 1]

(a) 0.686 mol (b) 1.46 mol (c) 83.8 mol (d) 24.7 mol

4 Which of the following acids is a strong acid ? .....

(a) HF (b) KOH (c) $HClO_4$ (d) HClO

16.4 / 20 = 0.82 / 0.12

5 On dissolving 16.4 g of HF in water, a solution its volume is 2×10^2 mL and its concentration is ..... is formed.

[H = 1 , F = 19]

(a) 0.82 M (b) 0.16 M (c) 0.08 M (d) 4.1 M

6 What is the type of the compound which dissolves in water and does not dissolve in benzene ? .....

(a) polar only. (b) nonpolar only.

(c) polar or nonpolar. (d) polar or ionic.

7 The separating funnel showed in the opposite figure is used to separate the components of ..... mixture.

(a) cobalt (II) chloride in water
(b) aqueous solution of cobalt (II) chloride in kerosene
(c) milk
(d) copper sulphate in water

8 Which of the following choices expresses the dimensions of two dimensional nano substances ? .....

Choices	Length	Width	Height
(a)	1.2×10^{-11} m	200×10^{-10} m	320×10^{-12} m
(b)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(c)	130×10^{-7} m	49×10^{-7} m	68×10^{-6} m
(d)	17×10^{-8} m	83×10^{-4} m	96×10^{-3} m

9 If the formula of antimony oxide is Sb_2O_3 and that of sodium phosphate is Na_3PO_4, what is the formula of antimony phosphate ? .....

(a) $SbPO_4$
(b) Sb_2PO_4
(c) $Sb_2(PO_4)_3$
(d) Sb_3PO_4

10 20 mL of carbon monoxide gas combust in excess of oxygen according to the equation :

$$2CO_{(g)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)}$$

What is the produced volume of carbon dioxide gas (at STP) ? .....

(a) 20 mL
(b) 40 mL
(c) 60 mL
(d) 80 mL

11 A chemical reaction is expressed by the opposite symbolic equation :

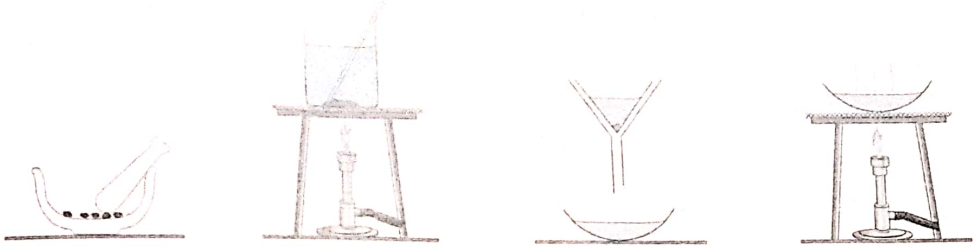
$$aA + bB \longrightarrow cC + dD$$

What is the number of possible values of the value $\frac{c}{d}$? with explanation.

Only one value, as the ratio of coffecients in the balanced equation is constant

1 mark

12 The following figures express the steps of preparation of the pure crystals of one of the salts :



(1) (2) (3) (4)

Mention the name of a salt can be prepared by this method. With explanation.

NaCl, Soluble salt as it Soluble in water and can be obtained by evaporation of water from solution

1 mark

13 In the chemical reaction illustrated by the following equation :

$$CH_3COOH_{(aq)} + NH_{3(g)} \rightleftharpoons CH_3COO^-_{(aq)} + NH^+_{4(aq)}$$

Relate each compound or ion in the previous equation with the appropriate term of the following :

conjugate base | acid | conjugate acid | base

acid + base ⇌ Conjugate base + Conjugate acid

1 mark

0.46 0.0149

14 In the reaction : $Ca_3(PO_4)_2 + 3H_2SO_4 \longrightarrow 3CaSO_4 + 2H_3PO_4$

129 g of $Ca_3(PO_4)_2$ was added to 4.4 g of H_2SO_4,

illustrate by chemical calculations the limiting reactant for this reaction.

[$Ca_3(PO_4)_2$ = 310 g/mol , H_2SO_4 = 98 g/mol]

$Ca_3(PO_4)_2 \rightarrow 3CaSO_4$

1 mole → 3 mole

310 → 3 mole

129 → ?

$? = \frac{129 \times 3}{310} = 1.248$ mol

$3H_2SO_4 \rightarrow 3CaSO_4$

3 mole → 3 mole

3 × 98 → 3 mole

294 → 3 mole

4.4 → ?

$? = \frac{3 \times 4.4}{294} = 0.044$

H_2SO_4 Consumed to produce less no. of $CaSO_4$ moles

H_2SO_4 is limiting reactant

2 marks

15 **Conclude the chemical formula** of rhenium chloride compound given that the percentage of rhenium Re in it is 63.6%

[Re = 186.2 , Cl = 35.5]

Assume mass of Compound = 100 g

	Re	Cl
mass	63.6	36.4
no. moles	$\frac{63.6}{186.2}$ = 0.341 mol	$\frac{36.4}{35.5}$ = 1.025 mol
Ratio	$\frac{0.341}{0.341}$ = 1	$\frac{1.025}{0.341}$ = 3 mol
Formula unit	$ReCl_3$	

2 marks

16 **What is the value** of 9.49 s in nanosecond unit ?

$9.49 s = 9.49 \times 10^9$ ns

1 mark

17 If you have 1 mL of each of colourless hydrochloric acid and phenolphthalein indicator.

How to differentiate between them by one practical experiment ?

* **Experiment :**

adding alkali solution to each of them (NaOH)

* **Observation :**

HCl remains colourless, Phenolphtalein change into pink

2 marks

Booklet model 7

Rate your level

★★★★ Superior	★★★ Remarkable	★★ above average	Weak
from 20 to 18 marks	from 17 to 14 marks	from 13 to 10 marks	less than 10 marks

Choose the correct answer for the questions 1 : 10. (10 marks)

1 Quantitative measurement .....

(a) includes a numerical value and a measuring unit.
(b) doesn't include a numerical value.
(c) always includes a comparison.
(d) is achieved through practical experiments.

2 All the chemical formulas of compounds shown in the following table are correct, except .....

(a)	(b)	(c)	(d)
Aluminum sulphate	Calcium nitrate	Iron (III) bromide	Potassium sulphide
$Al_2(SO_4)_3$	$Ca(NO_3)_2$	Fe_3Br	K_2S

3 An element (X) its gram atomic mass is 32 g/mol and its electronic configuration is (2 , 8 , 6), Another element (Y) its gram atomic mass is 35.5 g/mol and its electronic configuration is (2 , 8 , 7), What is the gram molecular mass of the compound produced from combining the atoms of the two elements (X) , (Y) ? .....

(a) 67 g/mol (b) 99 g/mol (c) 103 g/mol (d) 134 g/mol

4 Which of the following represents a pair of conjugate acid and base ? .....

(a) H_3PO_4 , PO_4^{3-} (b) $H_2PO_4^-$, PO_4^{3-} (c) H_3PO_4 , HPO_4^{2-} (d) $H_2PO_4^-$, HPO_4^{2-}

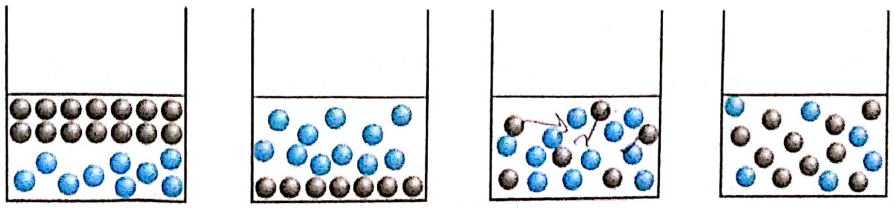
5 In which of the following compounds the mass percentage of hydrogen is higher ? .....

[H = 1 , Cl = 35.5 , O = 16 , S = 32]

(a) HCl (b) H_2O (c) H_2SO_4 (d) H_2S

6 Which of the following diagrams expresses the solution produced from dissolving sugar in water ? .....

Sugar particles
Water molecules



(a) (b) (c) (d)

7 **Which of the following statements is correct ?** .....

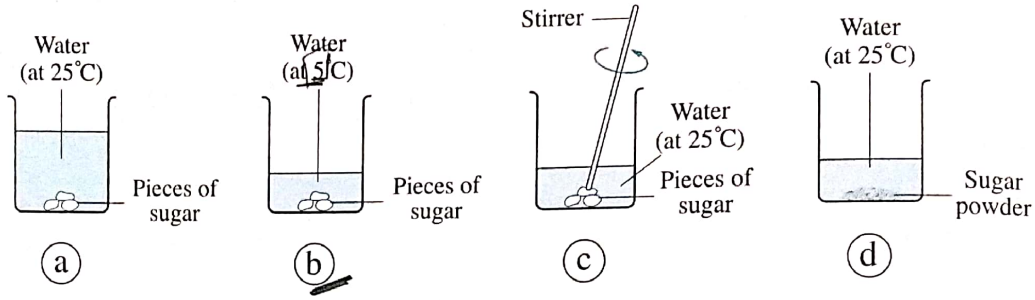
(a) The aqueous solution of magnesium oxide its pH value is less than 7

(b) The aqueous solution of sulphur trioxide its pH value is greater than 7

(c) Calcium oxide reacts with nitric acid forming salt and water.

(d) Carbon dioxide reacts with hydrochloric acid forming salt and water.

8 **In the experiment illustrated by the following figures, 2 g of sugar are used with different volumes of water at different temperatures, what is the state in which the dissolution process of solute in the solvent takes longer time ?** .....



(a) (b) (c) (d)

9 **According to the reaction :** $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

on adding 100 g of yeast to 1 mol of $C_6H_{12}O_6$, 32.3 g of C_2H_5OH are formed, what is the percentage of the actual yield of C_2H_5OH ? ..... [C = 12 , H = 1 , O = 16]

(a) 35.1%

(b) 17.5%

(c) 100%

(d) 32.3%

10 **What is the ionic equation which represents the formation of calcium carbonate salt, which is insoluble in water from the reaction of $CaCl_2$, Na_2CO_3 solutions ?** .....

(a) $Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow CaCO_{3(aq)}$

(b) $Na_2CO_{3(aq)} + CaCl_{2(aq)} \longrightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + CaCO_{3(s)}$

(c) $Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow CaCO_{3(s)}$

(d) $Na_2CO_{3(aq)} + CaCl_{2(aq)} \longrightarrow 2NaCl_{(aq)} + Ca^{2+}_{(s)} + CO^{2-}_{3(s)}$

11 **What is the difference between** silver nano particles **and** silver particles which can be seen by the naked eye ?

The nano particles are measured in nano scale, while the particles seen by naked eyes measured in macro scale

1 mark

12 **Show by symbolic equations**, which reacts with larger volume of hydrochloric acid. 1 mol of sodium carbonate or 1 mol of sodium bicarbonate ?

$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

(1 mol : 2 mol)

$NaHCO_{3(s)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

Na_2CO_3 reacts with larger volume of HCl, Bec, the volume of solution increases by increasing the number of moles.

2 marks

13 **Calculate the molality** of the solution produced from adding 0.25 mol of potassium bromide to 1.25 kg of water.

$m = \frac{\text{no of moles}}{\text{mass of solvent (kg)}} = \frac{0.25}{1.25} = 0.2\,m$

1 mark

14 **What does happen** when each of the following is added to a heterogeneous mixture of water and benzene ? **With explanation.**

(1) Oil.

oil will dissolve in benzene not water as it is non polar compound that dissolves in non polar solvent

(2) Potassium hydroxide.

it will dissolves in water as it ionic compound dissolves in polar solvents

1 mark

15 **Calculate the mass** of 37.8 L of methane gas (at STP). CH_4 [C = 12 , H = 1]

m.m = (12+4) = 16

$\frac{\text{mass}}{\text{m.m}} = \frac{V}{22.4} \Rightarrow \text{mass} = \frac{V \times \text{m.m}}{22.4} = \frac{37.8 \times 16}{22.4} = 27\,gm$

1 mark

16 **Calculate the mass** of phosphorus vapours [P = 31] that contains the same number of molecules which are found in 4.23 g of sulphur vapours [S = 32].

m m Phosphorus vapour $\Rightarrow P_4 = 4 \times 31 = 124$ g/mol

m m Sulphur vapour $\Rightarrow S_8 = 8 \times 32 = 256$ g/mol

no. of moles $= \frac{4.23}{256} = 0.0165$ mol

no. of mole cules = no. of molecules

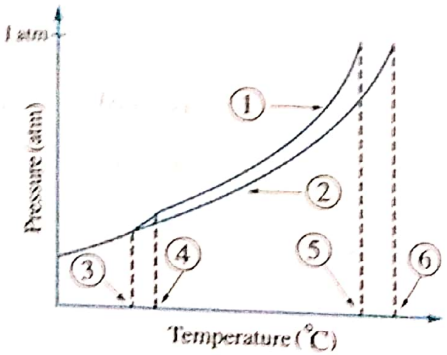
no. of moles = no. moles

mass = no. of moles $\times$ m.m $= 0.0165 \times 124 = 2.0489$ g

IP

2 marks

17 **The opposite graph represents** the relation between the vapour pressure of (pure water and an aqueous solution) and the temperature,



Write beside each term of the following the appropriate number that represents it (in the graph)

(1)	3	*freezing point of solution*	2	*vapour pressure of solution*	6	*boiling point of solution*
(2)	4	*freezing point of pure water*	1	*vapour pressure of pure water*	5	*boiling point of pure water*

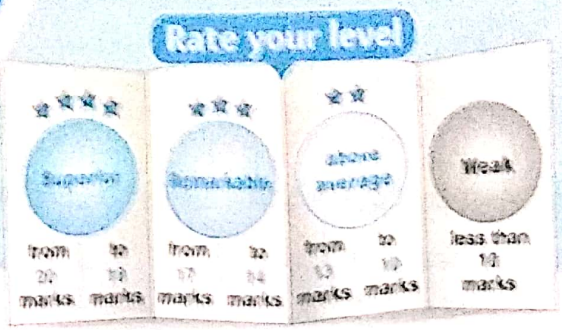
Which is greater :

the difference between the boiling points of pure water and the solution **or** the difference between the freezing points of pure water and the solution ?

The difference between boiling points is greater

2 marks

Booklet model 8



Choose the correct answer for the questions 1 : 10 — 10 marks

1 Which of the following prefixes do not represent its true value ? .....

(a) Mega = 10^6 units.
(b) Kilo = 1000 units.
(c) Deci = 10 units.
(d) Nano = 10^{-9} of the unit.

2 On mixing 2 mol of the substance (A) with 1 mol of the substance (B) according to the hypothetical equation : $3A + B \longrightarrow C + D$

Then the limiting reactant will be ..... , with explanation.

(a) A / Because its molar mass is the smallest.
(b) A / Because all its moles are consumed in producing the least number of products moles.
(c) B / Because the number of its moles is less than the number of moles of (A).
(d) B / Because 3 molecules of (A) react with 1 molecule of (B).

3 A sample of oxygen gas its mass is 32 g contains ..... [H = 1 , O = 16]

(a) 6.02×10^{23} oxygen atoms.
(b) 1.204×10^{24} oxygen molecules.
(c) the same number of oxygen atoms found in 18 g of water.
(d) the same number of oxygen atoms found in 36 g of water.

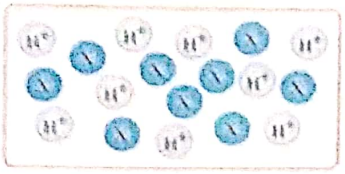
4 Why is glucose soluble in water, while benzene is not, inspite of both being organic compounds ? .....

(a) due to difference of their molar masses.
(b) because glucose is an ionic compound, while benzene is a covalent compound.
(c) because glucose is a strong electrolyte, while benzene is a weak electrolyte.
(d) because glucose contains polar O – H bonds, while benzene contains C, H only.

5 On measuring the boiling and freezing points of an aqueous solution of sodium chloride the readings of the two thermometers were .....

(a) 98°C, –1.6°C (b) 100°C, 0°C (c) 102°C, –1.6°C (d) 102°C, 0°C

6 On adding HX acid to water with stirring, there are two probabilities shown in the following figures :



the first probability

the second probability

HX acid acts in .....

(a) the first probability as a weak acid and the second probability as a strong acid.

(b) the first probability as a strong acid and the second probability as a weak acid.

(c) the two probabilities as a weak acid.

(d) the two probabilites as a strong acid.

7 One of the most famous sauces is prepared by whipping egg yolks, and during continuous whipping, oil is added drop by drop, then afterwards drops of vinegar are added, what is the classification of the mixture which composes this sauce ? .....

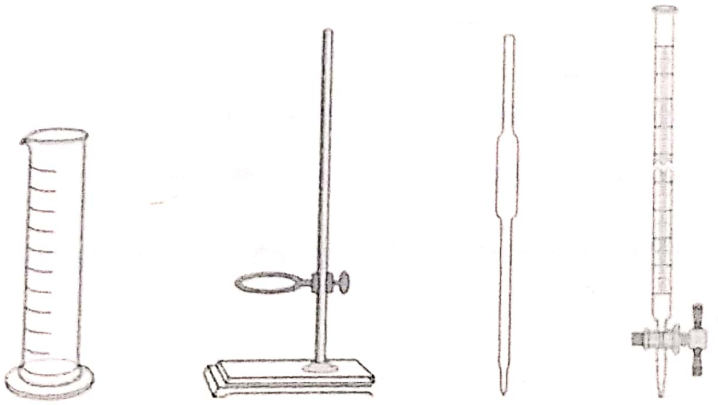
(a) Colloid (liquid in liquid).

(b) Colloid (liquid in solid).

(c) Suspension (solid in liquid).

(d) Solution (gas in liquid).

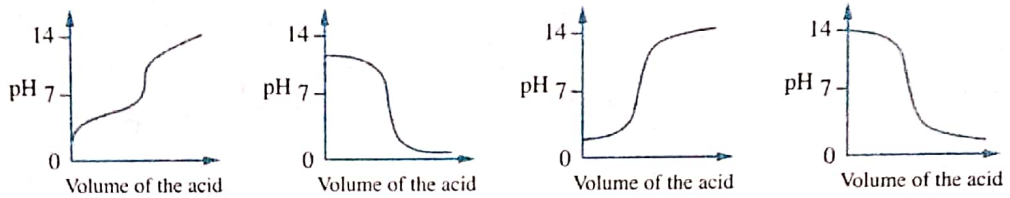
8 Which of the following tools would be used in a titration process ? and what is the missing tool ? .....



(1) (2) (3) (4)

Choices	Used tool	Missing tool
(a)	(1) , (2)	Glass beaker
(b)	(2) , (3)	Analytical balance
(c)	(1) , (4)	Round - bottom flask
(d)	(2) , (4)	Conical flask

9 **Which of the following curves represents the titration of a weak base with a strong acid ?** .....



10 **Which of the following equations represents correctly the reaction of sodium carbonate solution with sulphuric acid ?** .....

(a) $Na_2CO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(s)} + H_2O_{(\ell)} + CO_{2(g)}$

(b) $CO^{2-}_{3(aq)} + 2H^{+}_{(aq)} \longrightarrow H_2O_{(\ell)} + CO_{2(g)}$

(c) $Na^{+}_{(s)} + CO^{2-}_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(\ell)} + CO_{2(g)}$

(d) $CO^{2-}_{3(s)} + 2H^{+}_{(aq)} \longrightarrow H_2O_{(aq)} + CO_{2(g)}$

11 "Science fiction is becoming by time and efforts touchable facts"

Clarify the previous statement in the light of astronomers expectations regarding the use of carbon nano tubes.

Carbon nano tubes are very hard and very light, which may use in making spaceshuttles and elvpators...

1 mark

12 **Calculate the molality** of the solution produced from dissolving 2.7 g of CH_3OH in 25 g of H_2O

[C = 12 , H = 1 , O = 16]

no. of moles = $\frac{\text{mass}}{\text{molar mass}} = \frac{2.7}{32} = 0.0844$ mole

molality = $\frac{\text{no. moles}}{\text{mass of solvent in Kg}} = \frac{0.0844}{0.025} = 3.375$ m

2 marks

13 Solid indium element reacts with chlorine to form $InCl_3$

What is the value of the coefficient of $InCl_3$ in the balanced chemical equation of the reaction ?

$2In + 3Cl_2 \longrightarrow 2InCl_3$

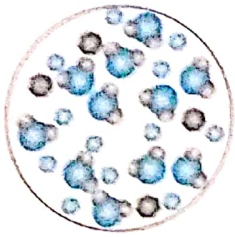
Coefficient = 2

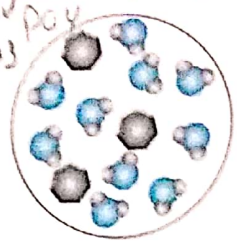
1 mark

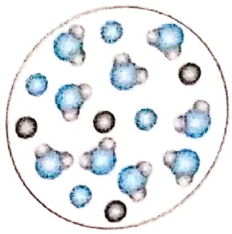
?

14 The following figures represent the solutions of three different compounds which are :

- Sodium chloride.
- Potassium phosphate.
- Glucose.







(1) Potassium phosphate (2) Glucose (3) Sodium Chloride

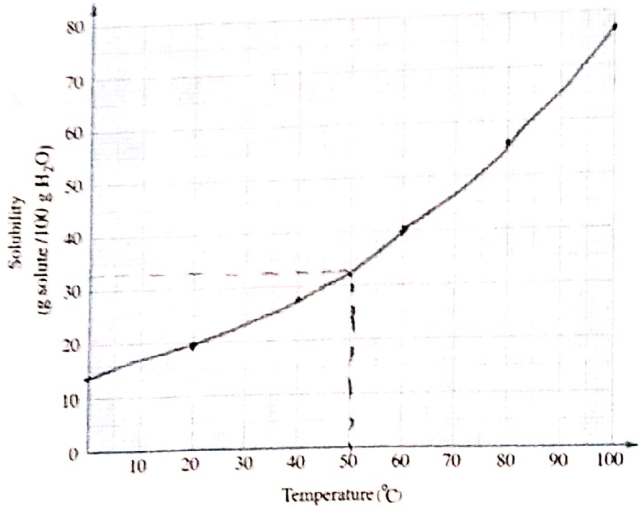
Write below each figure the chemical formula of the compound which represents it. (2 marks)

K_3PO_4 $C_6H_{12}O_6$ NaCl

15 The following table shows the masses of copper (II) sulphate required to be dissolved in 100 g of water to make several saturated solutions at different temperatures :

Temperature (°C)	0	20	40	60	80	100
Solubility (g solute/100 g H_2O)	14	20	28	40	56	77

(1) Use the values shown in the previous table to draw the solubility curve of copper (II) sulphate.



(2) What is the maximum mass of copper (II) sulphate can be dissolved in 100 g of water at 50°C ?

33 ≈ 34 gm (1 mark)

16 Complete the following equation : $H_2SO_{4(aq)} + H_2O_{(l)} \longrightarrow$ ... $HSO_4^- + H_3O^+_{(aq)}$

and why water is classified in this process as a base ?

water is base as it accepts the H^+ Proton. (1 mark)

17 4 balloons are inflated with four different gases at the same conditions of temperature and pressure, the mass of :

[H = 1]
[He = 4]
[Ne = 20]
[O = 16]

- Hydrogen gas in the first balloon was 0.02 g
- Helium gas in the second balloon was 0.04 g
- Neon gas in the third balloon was 0.2 g
- Oxygen gas in the fourth balloon was 0.32 g

Arrange these balloons according to their volume, explain your answer with chemical calculations.

no. of moles = mass / molar mass

$H_2 = \frac{0.02}{1} = 0.01$ mole

$He = \frac{0.04}{4} = 0.01$ mole

$Ne = \frac{0.2}{20} = 0.01$ mole

Ballons are equals in volumes as they Contains 0.01 mole and according Avagdros Postulates they are equal of volumes of containg same no. of volumes.

2 marks

Booklet model 9

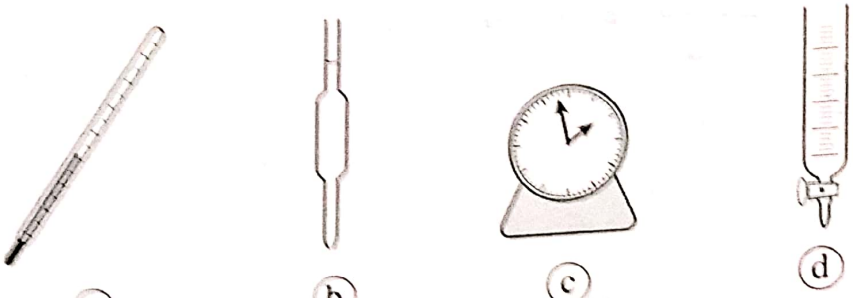
Rate your level

Superior	Remarkable	above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

10 marks

Choose the correct answer for the questions 1 : 10 .

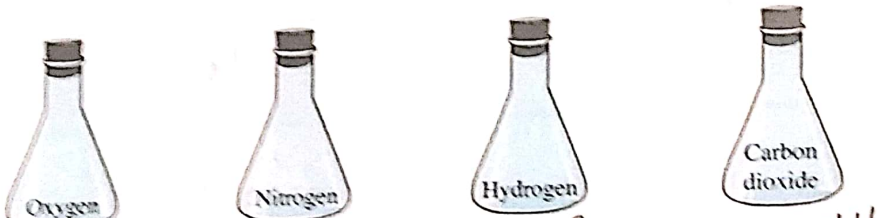
1 One of the students performed an experiment to measure the change in temperature on adding 25 mL of dilute hydrochloric acid to different volumes of sodium hydroxide solution, which of the following tools the student would not need during the performance of the experiment ? .....



(a) (b) (c) (d)

2 In front of you 4 similar flasks contain four different gases at the same conditions of pressure and temperature, which of these flasks its molar mass is larger ? .....

[O = 16 , N = 14 , H = 1 , C = 12]



(a) (b) (c) (d)

3 Which of the following ions can not behave as a base and as an acid in different reactions ? .....

(a) $H_2PO_4^-$ (b) CO_3^{2-} (c) HCO_3^- (d) HSO_4^-

4 What is the anion that exists in greater concentration in the solution which is produced from the reaction of 0.1 mol of H_3AsO_4 acid with 0.1 mol of sodium hydroxide ? .....

(a) $HAsO_4^{2-}$ (b) OH^- (c) $H_2AsO_4^-$ (d) Na^+

5 Sodium sulphate salt is found in many crystalline forms, Which of the following sodium sulphate crystalline salts loses 43.2% of its mass on complete evaporation of all water present in it ? ..... [Na = 23 , S = 32 , O = 16 , H = 1]

(a) $Na_2SO_4.H_2O$ (b) $Na_2SO_4.2H_2O$ (c) $Na_2SO_4.6H_2O$ (d) $Na_2SO_4.8H_2O$

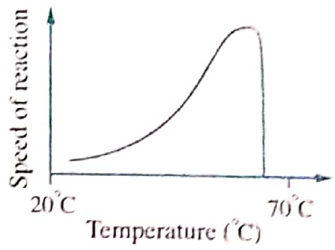
6 A solution is prepared by dissolving 1.25 mol of an unknown substance in 1000 g of pure water, which of the following by measuring it we can conclude that the solute is an electrolyte or nonelectrolyte ? .....

(a) Temperature of water.
(b) Freezing point of solution.
(c) Volume of solution.
(d) Molar concentration of solution.

7 Which of the following ions produces gas bubbles on adding hydrochloric acid to its solid salt ? .....

(a) Cu^{2+} (b) Fe^{3+} (c) Al^{3+} (d) CO_3^{2-}

8 The opposite graphical figure represents the effect of temperature on the activity of one of the human digestive enzymes, this represents the integration between chemistry and .....



(a) physics.
(b) biology.
(c) pharmacy.
(d) agriculture.

9 Which of the following represents an empirical formula and a molecular formula in the same time ? .....

(a) C_5H_{12} (b) C_5H_{10}
(c) C_4H_8 (d) C_4H_{10}

10 Ethane gas reacts with oxygen according to the equation :

$$2C_2H_{6(g)} + 7O_{2(g)} \xrightarrow{\Delta} 4CO_{2(g)} + 6H_2O_{(v)}$$

What is the volume of CO_2 (at STP) which is produced when 4 L of ethane gas reacts with excess of oxygen ? .....

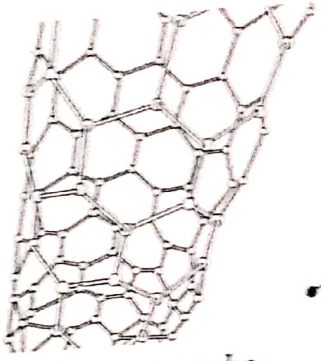
(a) 2 L (b) 3 L (c) 4 L (d) 8 L

11 How can the reaction of a concentrated solution of NaOH with 1 M $(NH_4)_2SO_4$ solution be indicated ? Write the balanced symbolic equation including the physical states of reactants and products.

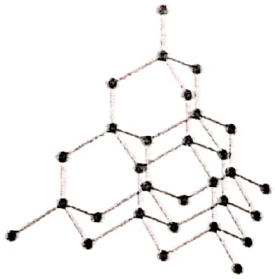
$(NH_4)_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + 2NH_{3(g)}$

We can indicate this by the evolving of ammonia gas with pungent smell (2 marks)

12 The opposite two figures show the molecular structure of diamond and carbon nano tubes :



Carbon nano tube



Diamond

(1) Which of them is preferred as a heat conductor, diamond or carbon nano tubes ?

Carbon nano tubes

(2) Which is harder, carbon nano tubes or steel ? and why ?

Carbon nanotubes
Due to strong bonds between
more carbon

1 mark

13 Chloroethene compound C_2H_3Cl reacts with oxygen according to the equation :

$$2C_2H_3Cl_{(g)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 2H_2O_{(v)} + 2HCl_{(g)}$$

Calculate the number of H_2O molecules produced from reaction of 10 mol of C_2H_3Cl with excess of oxygen gas.

$2C_2H_3Cl \rightarrow 2H_2O$
2 mole $\rightarrow$ 2 mole
1 mole $\rightarrow$ 1 mole
10 mole $\rightarrow$ 10 mole
no. of moles of H_2O = 10 mole
no. of molecules = no. moles × Av. no.
$10 \times 6.02 \times 10^{23}$
$= 6.02 \times 10^{24}$ molecules

2 marks

14 Calculate the mass of magnesium oxide that can be obtained by reacting a sample of magnesium its mass is 2.4 g with excess of oxygen. [Mg = 24 , O = 16]

$2MgO + O_2 \rightarrow 2MgO$
$2Mg \rightarrow 2MgO$
2 mole $\rightarrow$ 2 mole
$2 \times 24 \rightarrow 2(24+16)$
$2.4 \rightarrow x$
$x = \frac{80 \times 24}{48} = 4.8$ gm

1 mark

15 According to the reaction shown by the equation :

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

What is the limiting reactant on mixing 1.5 mol of O_2 with 2.5 mol of SO_2 ?

$2SO_2 \rightarrow 2SO_3$ | $O_2 + 2SO_3$

2 mole $\rightarrow$ 2 mole | 1 mole $\rightarrow$ 2 mole

2.5 mole $\rightarrow$ X | 1.5 mole $\rightarrow$ X

$X = \frac{2 \times 2.5}{2} = 2.5$ mole | $X = \frac{2 \times 1.5}{1} = 3$ mole

SO_2 amount consumed to produce less amount of SO_3 moles

SO_2 is limiting reactant.

2 marks

16 **Plan a practical experiment** to prepare 3 L of K_3PO_4 solution with 0.2 M concentration Given that the molar mass of K_3PO_4 compound equals 212 g/mol

no.moles = Molarity x Volume of solution = $0.2 \times 3 = 0.6$ mol

mass = no. of moles x molar mass = $0.6 \times 212 = 127.2$ gm

add 127.2gm of K_3PO_4 to 1 L of water and stir till complete dissolution Complete the solution by water till 3L.

2 marks

17 **Calculate the depression in the freezing point of water**, when an amount of nickel (II) nitrate salt is dissolved in it to form a solution, its molal concentration is 1 m, knowing that the molal freezing point depression constant of water is 1.86°C.kg/mol

Depression in freezing point = $\Delta t = K_f \, m_{solute}$

$= 1.86 \times 1 = 1.86$°C

1 mark

Booklet model 10

Rate your level

★★★★ Superior	★★★ Remarkable	★★ above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

Choose the correct answer for the questions 1 : 10 . (10 marks)

1 Uranium is supposed to exist in earth's crust in ratio of 4 g for each 1 ton of earth's crust, what is the mass of uranium exist in 1.5 mg of earth's crust ? .....

(a) 6 nanogram. (b) 6 microgram. (c) 6 milligram. (d) 6×10^{-5} gram.

2 What does happen on mixing two equal volumes of 0.2 M K_2CO_3 solution with 0.2 M Na_3PO_4 solution ? .....

(a) No precipitate is formed.
(b) A precipitate of K_3PO_4 is formed.
(c) A precipitate of Na_2CO_3 is formed.
(d) A precipitate of $K_3PO_4 . Na_2CO_3$ is formed.

3 The conjugate base of water is .....

(a) O^{2-} (b) OH^- (c) H_3O^+ (d) H_2O_2

4 Which of the following choices is chemically correct ? .....

Choices	Strength of acid	Concentration of acid	pH
(a)	Strong	0.01 M	2
(b)	Weak	0.01 M	1
(c)	Strong	3 M	5.5
(d)	Weak	3 M	– 0.5

5 The following solutions are equal in concentration, Which of them is alkaline ? .....

(a) LiCl (b) K_3PO_4 (c) $NaClO_4$ (d) NH_4NO_3

6 Phosphorus P_4 can be prepared from the following reaction :

$$2Ca_3(PO_4)_2 + 6SiO_2 + 10C \longrightarrow 6CaSiO_3 + 10CO + P_4$$

	$2Ca_3(PO_4)_2$	$6SiO_2$	$10C$
Molar mass	310 g/mol	60 g/mol	12 g/mol
Masses present in reaction medium	3370 g	1795 g	650 g

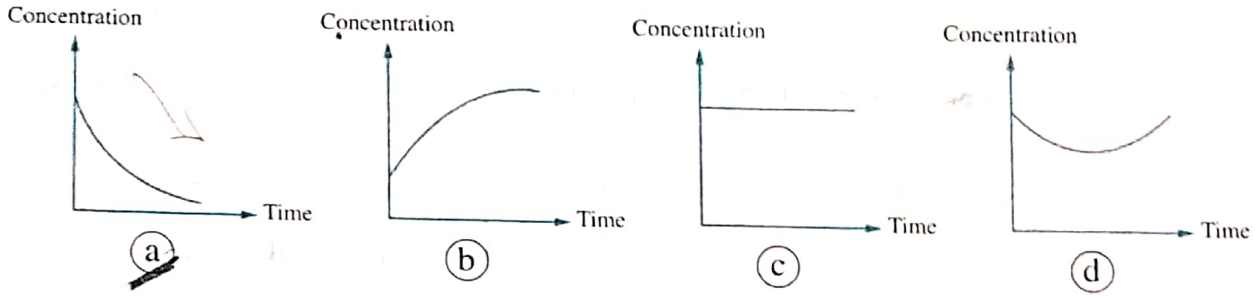
What is the limiting reactant for this reaction ? .....

(a) C (b) $Ca_3(PO_4)_2$ (c) SiO_2 (d) P_4

7 Which of the following values is not followed by a measuring unit ? .....

(a) Molar mass.
(b) Nano shell diameter.
(c) Molal concentration.
(d) pH

8 A mixture of ethanol (its boiling point is 78°C) and water (its boiling point is 100°C) can be separated by fractional distillation method, which of the following graphs expresses the concentration of the mixture by time ? .....



9 A sample of potassium chlorate $KClO_3$ was heated in an open test tube, so it decomposed according to the equation :

$$2KClO_{3(s)} \xrightarrow{\Delta} 2KCl_{(s)} + 3O_{2(g)}$$

What is the percentage of the lost substance of potassium chlorate at the end of the reaction ? .....

[K = 39 , Cl = 35.5 , O = 16]

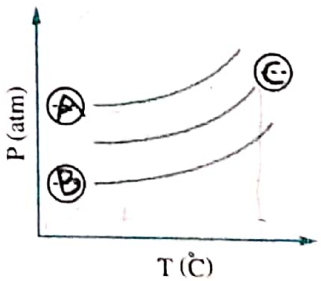
(a) 12%
(b) 28%
(c) 39%
(d) 30%

10 The mixture of mud in water is .....

(a) a heterogeneous colloidal mixture.
(b) a homogeneous suspension mixture.
(c) a solution whose contents can not be separated by filtration.
(d) a suspension mixture whose contents can be separated by filtration.

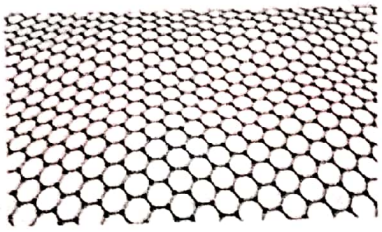
11 The opposite graph represents the vapour pressure curves for two pure liquids (A) and (B) and the solution resulted from mixing them (C).

If the liquid (A) is more volatile than the liquid (B), indicate each curve by one of the letters (A) , (B) or (C).

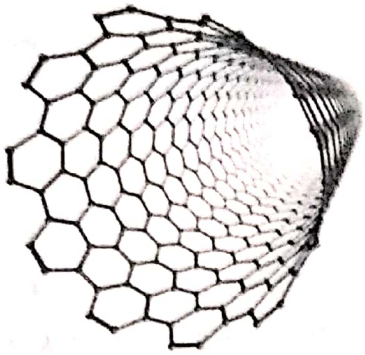


1 mark

12 The following three figures show the structure of graphene film which can be converted into single-walled carbon nano tubes and Bucky ball :



Graphene



Carbon nano tube

Bucky ball

(1) Compare between the rings forming each of graphene and Bucky ball "**in terms of :** number of carbon atoms of each ring".

in graphene consists of 6 Carbon atoms

bucky ball Consists of 5 Carbon atom

(2) Mention another difference between carbon nano tube and Bucky ball **"other than the geometrical shape of carbon rings".**

nano tubes 2 dimensional

bucky ball is 3 dimensional

2 marks

13 The blood of adult person contains about 2.64×10^{13} red blood cells, the mass of iron in it is 2.9 g, Calculate the number of iron atoms in each red blood cell. [Fe = 55.85]

2.64×10^{13} ⟶ 2.9

1 ⟶ x

$x = \frac{2.9}{2.64 \times 10^{13}} = 1.098 \times 10^{-10}$ gram

no. of moles in each cell $= \frac{1.098 \times 10^{-10}}{55.85} = 1.966 \times 10^{-12}$

no. of atoms = no. of moles $\times$ Avogadro no.

$= 1.966 \times 10^{-12} \times 6.02 \times 10^{23} = 1.18 \times 10^{12}$ atom

2 marks

14 Calculate the molar mass of the compound produced from the combination of potassium, and selenium which is located below oxygen in the modern periodic table.

[K = 39 , Se = 79]

K^{+1} Se^{-2}

K_2Se $[2\times39+79]=157$

1 mark

15 Calculate the percentage of the practical yield,

when 5 g of ethanol C_2H_5OH react with excess of potassium permanganate $KMnO_4$ to form 4.24 g of acetic acid CH_3COOH according to the equation :

$$3C_2H_5OH + 4KMnO_4 \longrightarrow 3CH_3COOH + 4MnO_2 + 4KOH + H_2O$$

[C = 12 , H = 1 , O = 16]

$3C_2H_5OH \rightarrow 3CH_3COOH$

3 mole $\rightarrow$ 3 mole

$3(2\times12+6+16) \rightarrow 3\times[2\times12+4+32]$

138 $\rightarrow$ 180

5 $\rightarrow$ x

$x = \frac{5\times180}{138} = 6.52$ gm

% of actual yield $= \frac{\text{actual}}{\text{theoritical}} \times 100 = \frac{4.24}{6.52} \times 100 = 65\%$

2 marks

16 Write the chemical equations that represent the formation of the solution of each of the following substances :

(1) $Na_2SO_{4(s)}$ (strong electrolyte).

$Na_2SO_4 \xrightarrow{H_2O} 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

(2) $CH_4N_2O_{(s)}$ (nonelectrolyte).

$CH_4N_2O_{(s)} \xrightarrow{H_2O} CH_4N_2O_{(aq)}$

(3) $HBrO_{(aq)}$ (weak electrolyte).

$HBrO_{(aq)} \rightleftharpoons H^+_{(aq)} + BrO^-_{(aq)}$

1 mark

17 An unknown compound contains 24.2% carbon, 4% hydrogen and the rest is chlorine, what is the molecular formula of this compound ? given that molar mass is 150 g/mol

[C = 12 , H = 1 , Cl = 35.5]

assum mass 100

	Cl	C	H
mass	71.8	24.2	4
no. of moles	$\frac{71.8}{35.5}$	$\frac{24.2}{12}$	$\frac{4}{1}$
Ratio	2	2	4
	1	1	2

Empirical CH_2Cl

Molar mass of empirical = (12 + 2 + 35.5) = 49.5

no of units = $\frac{\text{molar mass}}{\text{empirical molar mass}} = \frac{150}{49.5} \approx 3$

molecular formula = $C_3H_6Cl_3$

2 marks